Received: 18 May 2022 | Revised: 2 May 2023 | Accepted: 13 May 2023
DOI: 10.1002/ajp.23524

RESEARCH ARTICLE

AMERICAN JOURNAL OF PRIMATOLOGY WILEY

Welfare assessment of slow loris (*Nycticebus* spp.) at an Indonesian primate rehabilitation center: Development and validation of body condition score

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Abstract
Body condition scoring (BCS) assessment can reflect animal welfare status and help the veterinarian to make a quick health management decision, including for confiscated slow loris (*Nycticebus* spp.). The confiscated slow loris should be rehabilitated in a rehabilitation center before being released. It is essential to monitor the welfare of slow loris to ensure that candidates are released. Assessment of animal welfare status requires representative measurable criteria and indicators. However, there is no standardized BCS for slow loris yet. This study focuses on developing and validating BCS based on body weight and circumference. In this study, 180 individuals were evaluated and scored. We measured body weight and circumferences to validate the assessment of BCS. There are no significant differences in body weight and circumferences within species and sexes. Muscle mass and fat deposits were palpated, visually viewed, and grouped in five BCS. There was a significant difference in body weight and circumference between BCS levels. According to this study, the development of BCS is valid and can be used to slow loris in prevailing circumstances and any ex-situ facilities.

KEYWORDS
BCS, body circumference, body weight, nocturnal primate

1 | INTRODUCTION

The illegal wildlife trade threatens the survival of thousands of species globally (Nijman et al., 2019). The slow lorises (*Nycticebus* sp.) are a group of small nocturnal strepsirrhine primates found distributed across South and Southeast Asia (Nekaris et al., 2013). In Indonesia, despite their protected status, slow lorises are among the most commonly traded primates in domestic markets (Nijman et al., 2015). Their cute appearance makes them highly sought after as exotic pets. All nine species, seven of which are found in Indonesia, are considered threatened according to the International Union for Conservation of Nature. When law enforcement of illegal trade occurs and confiscations of animals are made, slow lorises are typically sent to government facilities or specialist primate rescue centers (Moore et al., 2014).

During their period in trade, many slow lorises having recently been poached from the wild are then subjected to hot, cramped, and crowded conditions during transportation to or while on display in the markets. Of the slow lorises rescued from trade, many arrive at transit or rescue centers in poor health and are often injured,

Abbreviations: BCS, body condition score; df, degrees of freedom; g, gram; IACUC, Institutional Animal Care and Use Committee; MANOVA, multivariate analysis of variance; mm, millimeter; n, number; P, *p*-value; PCA, principal component analysis; PRC, Primate Research Centre; SD, standard deviation; SPSS, Statistical Package for Social Sciences; t, *t*-test; YIARI, Yayasan Inisiasi Alam Rehabilitasi Indonesia.

malnourished, and dehydrated (Fuller et al., 2017). Furthermore to reduce the chance of being bitten by the slow loris during handling and to prevent them from wounding conspecifics while being stored in close proximity, traders routinely break or cut the teeth of slow lorises using pliers, wire cutters, or nail clippers (Moore et al., 2014; Nekaris et al., 2015; Rode-Margono & Nekaris, 2015). The extremely painful procedure of teeth clipping can lead to severe health problems such as periodontitis, gingivitis, and abscesses, making it challenging for the animal to feed on its preferred food and can even result in mortality if left untreated (Moore et al., 2015; Priambada et al., 2018). In 2015, during the height of the slow loris trade, it was reported that more than 80% of the slow lorises arriving at a primate rescue center in West Java, had dental problems resulting from this teeth-clipping process (Moore et al., 2015).

The main goal of most rescue centers is to maintain the animals' normal physical and psychological health so that they may be released back into their natural habitat (Baker, 2002; Příbrský, 2020). The provision of optimal animal welfare during this time can speed up the slow loris rehabilitation process (Guy et al., 2014). For slow lorises that are unable to be released due to physical injuries or behavioral problems, the long-term sanctuary is provided (Fuller et al., 2017; Moore et al., 2014). Monitoring and evaluation of an animal's welfare status while in captivity are essential in the ex-situ conservation of slow lorises (Moore et al., 2014).

The five freedoms of animal welfare are a globally recognized standard for the welfare of animals under human control that encompasses the mental and physical well-being of animals. The five freedom consist of freedom from hunger and thirst; freedom from discomfort; freedom from injury, pain, and disease; freedom to express normal behavior; and freedom from fear and distress (Animal Welfare Committee, 2009). Subsequently, the five domains model was developed in response to the recognition of animal sentience and puts greater focus on the mental well-being of the animal, while also acknowledging that welfare can be both positive and negative (Mellor, 2017). The five domains are (1) nutrition, (2) environment, (3) health, (4) behavior, and (5) mental state. The concept of the five domains facilitates the improved ability to assess and measure welfare by recognizing these five elements and their interconnectedness (Mellor et al., 2020).

An animal in a good state of welfare is commonly regarded as being well nourished, safe, free of pain, fear, and suffering, and capable of developing and expressing species-typical relationships, behaviors, and cognitive abilities (Marchant-Forde, 2015). The needs of each species, and often the individual, can be different, therefore, measuring and ensuring the welfare goals are met requires a variety of tailored approaches. As an animal's welfare state is also susceptible to change temporally, with development, or with fluctuating external stressors, monitoring of associated goals should be assessed with regularity, even when management actions have not changed (Greggor et al., 2018).

The absence of a comprehensive reference or guide on the health and nutrition of slow lorises has made it difficult for ex-situ conservation agencies to accurately assess and monitor the health and welfare status of slow lorises. The nocturnal slow lorises are notably cautious and shy animals that are highly prone to both environmental and social stress (Moore et al., 2015; Khudamrongsawat et al., 2018). For captive animals, artificial light and handling by humans have been identified as potential stressors (Nekaris et al., 2016). As the handling of slow lorises during medical check-ups by trained practitioners at rescue centers is necessary, an alternative easy, inexpensive, and noninvasive method of assessing health and welfare would be preferable.

One such method of assessing the welfare status of an animal is the use of body condition score (BCS) (Pérez-Flores et al., 2016; Wijeyamohan et al., 2014). BCS is an easy, subjective semi-quantitative method of assessing body fat and muscle without the need for special equipment (Matthews et al., 2012; Reamer et al., 2020). BCS is useful for early diagnosis, prognosis, and monitoring in veterinary management programs (Burkholder, 2000). It can also be used to help make quick and informed decisions to mitigate human–animal interaction and animal confiscation regardless of sex or age class (Clingermann & Summers, 2012).

BCS systems have now been developed for several mammalian species, including dogs, cats, horses, cattle, mice, rhesus macaques, ring-tailed lemurs, and chimpanzees (Baldwin et al., 2010; Burkholder, 2000; Clingermann & Summers, 2012; Millette et al., 2015; Reamer et al., 2020; Ullman-Culleré & Foltz, 1999). The absence of a comprehensive reference on the health and nutrition of slow lorises has made it difficult for ex-situ conservation agencies, both for the public and for particular purposes, to assess and monitor the welfare status of slow lorises. A fast, easy, and inexpensive welfare assessment method is needed as a tool to monitor and evaluate ex-situ management of slow lorises.

For most species, the BCS scoring system requires a hands-on approach that involves a combination of palpation and visual assessments of the degree of fatness at a number of specific areas on the body (Summers et al., 2012). While arguably less accurate than the more invasive hands-on approach, some BCS systems have been developed purely on visual cues such as in the rhesus macaque (*Macaca mulatta*) (Berman & Schwartz, 1988).

This study aims to develop and validate a BCS standard for Indonesian slow lorises that can be used as an assessment tool to determine the welfare status using body weight and circumference. To be accepted as a valid and accurate method, each BCS system must be assessed in comparison with an objective means of measuring body composition (Clingerman & Summers, 2005). This study may contribute as an essential step to ex-situ conservation facilities monitoring welfare status.

2 | METHODS

2.1 | Study site and population

We conducted the study at the Primate Rehabilitation Center of Yayasan Inisiasi Alam Rehabilitasi Indonesia (YIARI), located in Bogor, Indonesia (6°39′46” S, −106°43′45” E, 695 m above sea level) from May 2021 to December 2021. The Ministry of Environment and Forestry of Indonesia worked in collaboration with YIARI to conserve Indonesian slow lorises. A function of the YIARI rehabilitation center is to rescue, rehabilitate, and where possible release slow lorises and other primates back to their natural habitat. YIARI has been receiving slow lorises from trade since 2008 (Moore et al., 2014). Slow lorises were housed in semi-natural enclosures in single, pair, or multiple groups based on each slow loris' individual characteristics.

We examined 180 adult slow lorises, 112 Javan slow lorises (comprising 43 males and 69 females) and 68 Sumatran slow lorises (comprising 41 males and 27 females), during their routine medical check-ups. We acknowledge there may be more than two distinct species of slow loris present in Sumatra, but for the purposes of this study, Sumatran slow lorises were grouped together due to the difficulties in accurately distinguishing between *Nycticebus coucang* and *N. hilleri* that originated from unknown origins.

The two Sumatran species possess very similar physical and morphological traits as well as a high-level of intraspecies variation (Nekaris & Jaffe, 2007; Ravosa, 1998). Moreover, as the only significantly different size and morphometric differences reported between *N. coucang* and *N. hilleri* were head breadth (larger in *N. coucang*) and brachial index (larger in *N. hilleri*), we felt confident that grouping the Sumatran species together would not affect the analyses in this study, which focused on the muscle and fat composition and proportion (Nekaris & Jaffe, 2007). the In addition, the range of *N. coucang* is much greater than that of *N. hilleri* which is restricted to the northern tip of Sumatra, and in much closer proximity to many of the known trade hubs in southern Sumatra and Java, therefore, it was deemed more likely that the slow lorises arriving in Java would have originated from this region rather than the more distant northerly region. Finally, as BCS is an assessment of body fat composition and proportion rather than size, the very subtle physical differences between *N. coucang* and *N. hilleri* would not affect the results of the assessment.

2.2 | Assessment of body condition for BCS

For the BSC assessments, we followed the same methods used for primates described by Clingerman and Summers (2005). A BCS was assigned to each individual slow loris based on both visual and palpatory assessments of fat, sub-subcutaneous fat, and muscle at specific anatomical points on the body including the upper arm, thorax cavity, abdominal cavity, pelvis, and thighs (Figure 1). The body condition assessment described the condition of bone prominence, muscle, and fat deposits of each individual with similar characteristics were grouped together.

The visibility and presence of the bones with respect to fat covering were described on a scale as being prominent; faintly visible but still easily palpable; not visible but can be palpated with a gentle touch; not visible and requires compression when palpated; or invisible and cannot be palpated. The muscle layers were described as

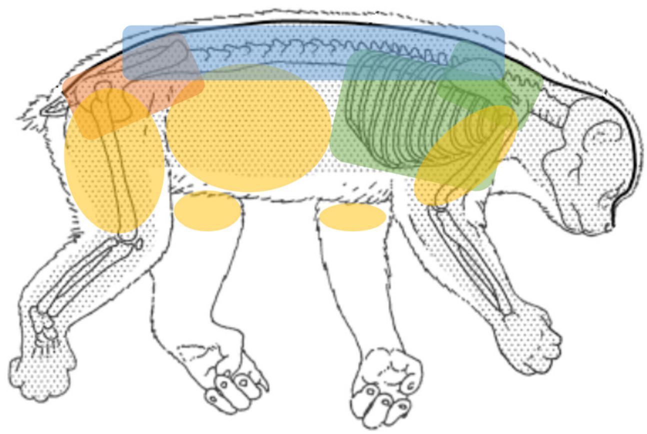

FIGURE 1 Slow loris' body anatomy on body condition assessment consisting of the pelvis (orange-colored), spine (blue-colored), thorax cavity (green-colored), subcutaneous fat, and fat deposits (yellow-colored). The picture was modified from Bottcher-Law et al. (2001).

very thin, thin, or thick. The fat layers were described as no fat, thin, medium, and thick. The visual and palpation assessments were carried out three times and a mean score was derived.

2.3 | Measurement of body circumferences and body weight weighing

Morphometric measurements of slow lorises were taken to validate the more subjective BCS. Body circumferences were taken in millimeters and body weight in grams. No anesthesia was required during the study. The circumference measurements of body parts were taken using a measuring tape (to the nearest 1 mm) and included the arm, thorax, abdominal, hip, and thigh (Pérez-Flores et al., 2016; Turner et al., 2016). The medial section of the humerus bone was used as an anatomical orientation for arm circumference; the fourth rib for thorax circumference; the medial section of the stomach for abdominal circumference; the ilium bone for hip circumference; and the medial part of the femur bone for thigh circumference, as shown in Figure 2. The slow lorises were then weighed using a hanging spring scale (Pesola®; to the nearest 1 g) after being placed in the pouch. The weight of the pouch was then subtracted from the total weight after the slow lorises were placed back into the enclosures.

2.4 | Data analysis

We used descriptive statistics to calculate the means and ranges for each of the different BCS. Body weight and body circumference measurements were compared individually against group and sex for differences using independent *t*-tests. Pearson's correlation tests were used to analyze the relationship between body weight and body circumference. We analyzed relationships between the BCS scores and the body weight and all the body circumferences measurements using Spearman's rank correlation coefficient due to the presence of ordinal data. Due to the high intercorrelation ($p < 0.001$) among body circumference variables ($n = 5$), we used a principal component analysis (PCA) to reduce our data set dimension. Factors with an eigenvalue >1 were extracted and used as our body circumference factor in the posterior analysis. Additionally, a Pearson's correlation test was run between the extracted factor, body weight, and BCS.

A three-way multivariate analysis of variance (MANOVA) was performed to determine the effect of BCS, group, and sex on both dependent variables: body weight and the body circumference factor. We then performed a series of one-way ANOVAs on each of the two dependent variables (i.e., body weight and body circumference factor) as a follow-up test to the MANOVA. Furthermore, a one-way MANOVA was performed separately on each group (Javan and Sumatran slow lorises) to evaluate the correlation of BCS with the two body measurements for each group individually. We analyzed all data using SPSS version 22. All test results with a p-value <0.05 were considered significant.

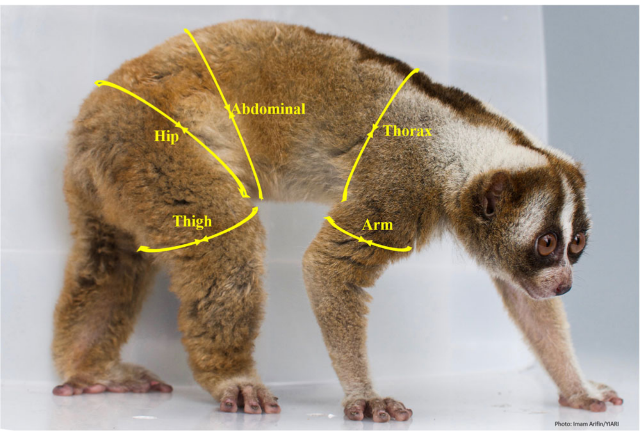

FIGURE 2 Orientation for body circumference measurement.

3 | RESULTS

3.1 | BCS assessment

Body condition was evaluated based on bones (hip, vertebrae, ribs, and scapula), muscles, and subcutaneous fat deposits (abdominal, inguinal, and axilla). From all slow lorises examined, we defined five different body condition categories based on differences in the body trunks (a combination of thorax, abdomen, and hips). Figures 3 and 4 show the dorsal and lateral presentation using the representative individuals as a model.

Emaciated slow loris exhibited a much wider thorax compared to the abdomen and hips, where the shape or silhouette forms an upturned triangle with an apex at the caudal region. Thin slow lorises also exhibited a wider thorax compared to the abdomen, but the difference was not so extreme at the hips producing a trapezoidal silhouette of the body with a smaller base at the caudal. Slow lorises with ideal body conditions displayed a balanced silhouette between the thorax, abdomen, and hips that form a rectangular shape. Overweight slow lorises were characterized by wider hips compared to their abdomen and thorax, forming a trapezoidal silhouette of their torso with a small base at the cranial. Obese slow lorises exhibited extreme hip width relative to the stomach and thorax forming a triangular silhouette of the torso with the apex at the cranial.

Assessment of the muscle mass and body fat composition showed distinct differences, both through visual and palpatory methods (Figure 5). The emaciated slow loris had a concaved abdomen towards the medial. Slow lorises with thin and ideal conditions had flat abdomen. The overweight slow lorises have a rounded abdomen that did not touch the floor. Obese slow lorises have an abdomen that extends to the ground.

3.2 | Comparison and validation with body weight and circumferences

Body weights of all slow lorises ranged from 561.67 to 1436.67 g with a mean of 920.08 g (SD = 148.13) (Table 1). For Javan slow

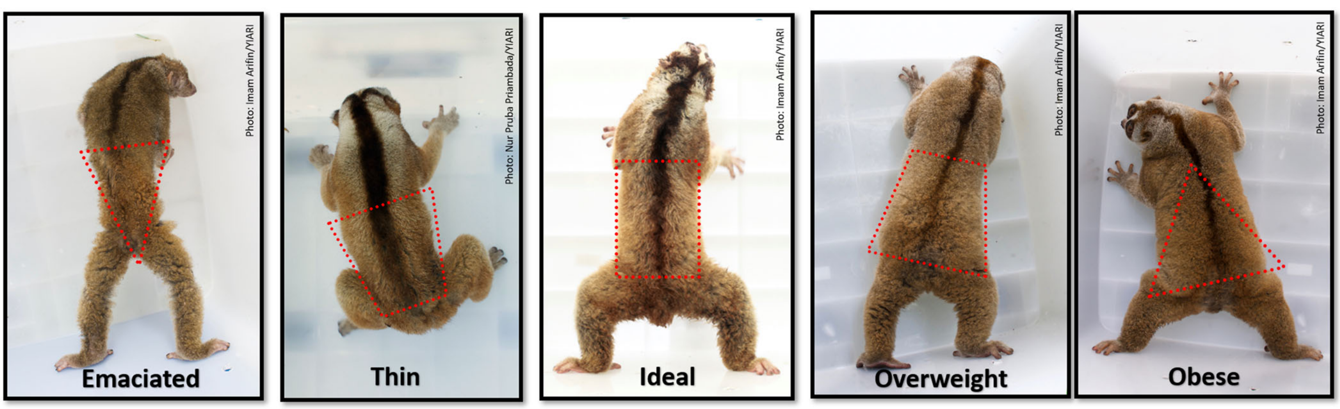

FIGURE 3 Dorsal presentation of slow loris' body condition types.

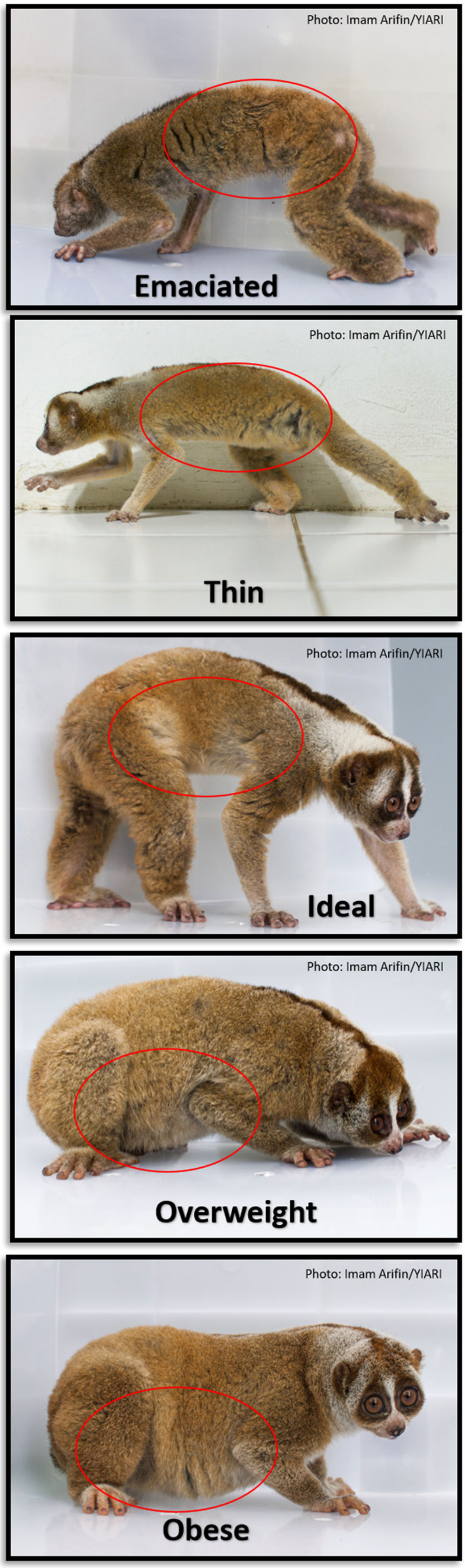

FIGURE 4 Lateral presentation of slow loris' body condition types.

lorises group, body weights ranged from 590.00 to 1320.00 g with a mean of 941.23 g (SD = 127.25). Sumatran slow lorises group ranged from 561.67 to 1436.67 g with a mean of 886.46 g (SD = 171.32).

According to the BCS system, BCS 1 represents an emaciated body condition, BCS 2 represents a thin condition, BCS 3 is the ideal condition, BCS 4 is an overweight condition, and BCS 5 is an obese condition (Figure 5). Only 1 individual slow loris had a BCS 1 (1%), 18 individuals had BCS 2 (10%), 121 individuals had BCS 3 (67%), 37 individuals had a BCS of 4 (21%), and 3 individuals had a BCS 5 (2%).

Body weight was moderately correlated with four body circumferences measurements (r range = 0.61–0.68, $p < 0.001$), and strongly correlated with thorax circumference ($r = 0.801$, $p < 0.001$) (Table 2). BCS was moderately correlated with all body measurement variables (ρ range = 0.574–0.651, $p < 0.001$) (Tables 3 and 4).

Body weight and circumferences for the stomach, hip, and thigh were significantly different between the two groups ($p < 0.05$, Table 5). Javan slow lorises had a higher mean body weight than Sumatran slow lorises (Table 1). However, Sumatran slow lorises had a higher mean of stomach, hip, and thigh circumferences (Table 5). Only body weight and stomach circumference were significant when considering differences in sex ($p < 0.05$) (Table 4) whereby female body weight and stomach circumference means were bigger than males (Tables 1 and 3).

The PCA comprising all five body circumferences variables returned an adequate Kaiser–Meyer–Olkin (KMO) of 0.857 (KMO values between 0.8 and 1 indicate the sampling is adequate) and a significant result for Bartlett's test of sphericity ($X^2 = 749.8$, $df = 10$, $p < 0.001$), meaning that our data were sufficiently correlated to perform the PCA. The PCA extracted one factor with eigenvalue >1, which explained 77% of the variance. The hip had the highest component in the factor, followed by the thigh and thorax (Table 6). The PCA factor extract (hereafter "body circumference factor") was significantly correlated with body weight ($r = 0.791$, $n = 176$, $p < 0.001$), and BCS ($\rho = 0.719$, $n = 176$, $p < 0.001$). There were no significant differences ($p > 0.05$) in the body circumference factor between group and sex.

A three-way MANOVA was conducted to test the hypothesis that there would be differences in the body measurements (i.e., body weight and body circumference factor) among BCS categories while accounting for the effect of group and sex and its interaction with BCS. We excluded both BCS 1 ($n = 1$) and BCS 5 ($n = 3$) from the analysis since these categories' sample sizes were very small. Since body weight was correlated with the body circumference factor, a MANOVA was an appropriate model to validate BCS. Additionally, the Box's M value of 46.858 was nonsignificant ($p < 0.05$), meaning that the covariance matrices between the groups were assumed to be equal for the purposes of the MANOVA. A statistically significant MANOVA effect for BCS (Wilks' $\lambda = 0.510$, $F[4, 326] = 32.595$, $p < 0.001$) and groups (Wilks' $\lambda = 0.822$, $F[2, 163] = 17.632$, $p < 0.001$) was obtained. No significant effect was found for sex and all four interactions [BCS*group, BCS*sex, group*sex, and

BCS	Status	Detail	Dorsal	Lateral	Oblique
1	Emaciated	The hip bones, spinosus processes, ribs, and scapula are prominent. The muscle layer is very thin in the arms and thighs. There is no fat layer on the stomach so it looks sunken.			
2	Thin	The hip bones, spinosus processes, ribs, and scapula are faintly visible but still easily palpable. Thin muscle layer on the arms and thighs. There is no fat layer on the stomach, but it looks flat.			
3	Ideal	The hip bones, spinosus processes, ribs, and scapula are not visible and can be palpated with a gentle touch. Thick muscle layer on the arms and thighs. The fat layer on the stomach is thin and looks flat.			
4	Over-weight	The hip bones, spinosus processes, ribs, and scapula are not visible and require compression when palpated. Thick muscle layer and thin fat layer on the arms and thighs. The fat layer on the belly is thick and looks rounded.			
5	Obese	The hip bones, spinosus processes, ribs, and scapula are invisible and cannot be palpated. The muscle layer on the arms and thighs is thick and saggy. The fat layer on the belly is massive and looks saggy.			

FIGURE 5 BCS of slow lorises using Javan slow lorises as models. Status and assessment detail of slow loris' BCS with three positions on each level. BSC, body condition score.

BCS*group*sex]. The multivariate BCS effect size (partial η^2) was estimated at 0.246, which implies that 24.6% of the variance in the canonically derived dependent variable was accounted for by BCS categories. The effect size for groups was 0.178, explaining 17.8% of the variance.

Before conducting a series of follow-up ANOVAs, the homogeneity of variance assumption was tested for both dependent variables. Based on nonsignificant Levene's F test results ($p > 0.05$), the homogeneity of variance assumption was considered satisfied. A series of one-way ANOVAs on each of the two dependent variables and for the three

TABLE 1 Body weight and circumference based on group and sex.

Slow lorises	Body weight (g) Range	Mean ± SD	Body circumference (mm) Range	Mean ± SD	*n*
Javan slow loris					
Male	650.000–1236.670	937.480 ± 125.520	595.00–803.890	692.550 ± 43.720	43
Female	590.000–1320.000	956.23 ± 136.780	531.67–841.670	707.050 ± 49.370	69
Sumatran slow loris					
Male	670.000–1223.330	866.420 ± 124.860	610.000–883.330	712.020 ± 60.630	41
Female	561.670–1436.670	933.460 ± 222.110	557.220–970.000	755.620 ± 104.500	27

TABLE 2 Body weight and circumference based on BCS.

BCS	Body weight (g) Range	Mean ± SD	Body circumference (mm) Range	Mean ± SD	*n*
1	590.000		557.220		1
2	561.670–960.000	773.430 ± 106.790	531.670–685.000	635.390 ± 38.420	18
3	670.000–1186.670	900.340 ± 108.650	627.780–883.330	698.430 ± 37.290	121
4	850.000–1320.000	1073.290 ± 126.880	676.670–918.330	780.730 ± 47.840	37
5	1083.330–1436.670	1284.440 ± 181.670	834.440–970.000	922.960 ± 76.710	3

Abbreviation: BCS, body condition score.

TABLE 3 Body circumference component based on BCS.

Body circumference	BCS 1	2	3	4	5
Arm					
Range		49.440–66.670	50.000–80.000	65.000–80.000	68.890–83.330
Mean ± SD		57.850 ± 4.630	65.540 ± 4.580	70.510 ± 3.750	77.960 ± 7.900
Thorax					
Range		151.670–178.330	160.000–200.000	175.000–220.000	212.220–226.110
Mean ± SD		167.980 ± 6.450	179.360 ± 7.460	191.170 ± 8.100	217.780 ± 7.350
Abdominal					
Range		135.830–200.000	164.440–243.330	178.330–276.670	242.220–291.110
Mean ± SD		181.450 ± 14.950	197.420 ± 13.430	224.160 ± 18.850	272.220 ± 26.270
Hip					
Range		130.000–171.110	146.670–233.330	163.330–253.330	200.560–246.670
Mean ± SD		151.220 ± 11.610	169.710 ± 13.420	194.650 ± 19.670	230.930 ± 26.310
Thigh					
Range		61.670–90.000	68.890–130.000	83.330–140.000	110.560–133.890
Mean ± SD		76.880 ± 6.960	86.410 ± 8.150	100.240 ± 11.030	124.070 ± 12.100

Abbreviation: BCS, body condition score.

independent factors were conducted as a follow-up test to the MANOVA (Table 7). BCS was found to have an effect on both body weight and body circumference factors (Table 7). Group had an effect only on the body circumference factor. Although sex had not a significant effect in the MANOVA model, when analyzing both dependent variables separately, sex had a significant effect in both variables.

A series of post hoc analyzes (Fisher's LSD) were performed to examine mean difference comparisons across the three BCS

TABLE 4 *T*-test for all body measurement variables between the two groups.

Dependent variable	*T*-test for equality of means			Descriptive analysis				
	t	*df*	Sig. (two-tailed)	Group	*n*	Mean	Standard deviation	Standard error mean
Weight	**2.304**	**114.903**	**0.0230***	Javan	112	949.03350	132.307950	12.501930
				Sumatran	68	893.03960	171.879860	20.843490
Arm	−0.8520	122.5170	0.3960	Javan	112	65.60750	5.447990	0.514790
				Sumatran	68	66.41160	6.522220	0.790940
Thorax	−0.9380	102.2920	0.350	Javan	112	180.53350	8.943450	0.845080
				Sumatran	68	182.27750	13.648220	1.655090
Stomach	**−2.520**	**99.4660**	**0.0130***	Javan	112	198.77120	17.109430	1.616690
				Sumatran	68	208.04310	27.252250	3.304820
Hip	**−2.9640**	**93.4360**	**0.0040***	Javan	112	169.82630	15.135480	1.430170
				Sumatran	68	180.33510	26.755330	3.244560
Thigh	**−2.6690**	**90.2930**	**0.0090***	Javan	112	86.74380	8.367920	0.790690
				Sumatran	68	92.26530	15.763010	1.911550

Abbreviation: BCS, body condition score.
*Significant results in bold.

TABLE 5 *T*-test for all body measurement variables between males and females for both groups.

Variable	Sex	Javan slow lorises						Sumatran slow lorises					
		t	*df*	*p*	*n*	Mean	SD	*t*	df	*p*	*n*	Mean	SD
Body weight	M	−0.7280	110	0.4680	43	937.50	125.520	−1.5910	66	0.1160	41	866.40	124.90
	F				69	956.20	136.780				27	933.50	222.10
Arm	M	0.1280	110	0.8980	43	65.70	5.760	0.4690	66	0.6410	41	66.70	5.80
	F				69	65.60	5.290				27	66.00	7.60
Thorax	M	−1.1520	110	0.2520	43	179.30	8.820	−1.8980	66	0.0620	41	179.80	11.40
	F				69	181.30	9.000				27	186.10	16.00
Stomach	M	**−2.5730**	**110**	**0.0110***	43	193.60	14.350	**−2.0700**	**66**	**0.0420***	41	202.60	19.90
	F				69	202.00	17.990				27	216.30	34.50
Hip	M	−0.7870	110	0.4330	43	168.40	13.720	**−2.3950**	**66**	**0.0190***	41	174.20	19.40
	F				69	170.70	15.990				27	189.60	33.50
Thigh	M	−1.2210	110	0.2250	43	85.50	7.920	**−2.4020**	**66**	**0.0190***	41	88.70	11.50
	F				69	87.50	8.610				27	97.70	19.60

*Significant results in bold.

categories. The results revealed that all post hoc mean comparisons were statistically significant ($p < 0.001$). The trend of the effect was linear, meaning that category 2 had a lower mean than category 3 and category 3 had a lower mean than category 4 (Figures 6–8).

Supplemental one-way MANOVAs were conducted for each group separately to verify the effect of BCS in each group individually. BCS had a significant effect in the multivariate analysis for both Javan slow lorises (Wilks' $\lambda = 0.438$, $F[4, 218] = 27.556$, $p < 0.001$) and Sumatran slow lorises (Wilks' $\lambda = 0.439$, $F[4,120] = 15.274$, $p < 0.001$). Follow-up ANOVAs also revealed a significant effect ($p < 0.001$) for each of the dependent variables for both groups.

The Pearson's correlation test revealed that body weight ($t = 12.43$, $df = 178$, $p < 0.05$) only had a moderately strong correlation (0.68) compared to body circumferences ($t = 18.168$, $df = 178$, $p < 0.05$) which had a very strong correlation with BCS (0.80). DMRT results showed that there were only four notations since BCS 2 was in the same notation as BCS 3 in body weight means. By contrast, body circumference was the same as BCS levels, resulting in five notations.

TABLE 6 Component value for each variable in the factor extracted in the PCA.

Component matrix	Body circumference factor 1
Arm	0.7860
Thorax	0.8960
Stomach	0.8920
Hip	0.9250
Thigh	0.9020

Abbreviation: PCA, principal component analysis.

4 | DISCUSSION

Mean body weights and a number of other body measurements between the two groups (Javan and Sumatran slow lorises) were significantly greater in Javan slow lorises, which is indeed the larger of the two species (Nekaris, 2014). Javan slow loris body weights ranged from 590.00 to 1320.00 g, and the greater slow loris ranged from 561.67 to 1436.67 g. These ranges were much broader than those reported in wild Javan slow lorises that ranged from 676 to 1150 g and the wild Greater slow loris ranging from 635 to 902 g (Cabana et al., 2017; Nekaris, 2014; Poindexter & Nekaris, 2017; Rode-Margono et al., 2014).

While most studies have not found slow lorises of any species to be sexually dimorphic, two reported the presence of sexual size

TABLE 7 Series of one-way ANOVAs results.

Source		Type III sum of squares	*df*	Mean square	*F*	Sig.	Partial η^2
Corrected model	Body weight	1,580,892.7220[a]	11	143,717.5200	12.3430	0.0000	0.4530
	BC factor	79.7900[b]	11	7.2540	20.3280	0.0000	0.5770
Intercept	Body weight	46,564,331.1210	1	46,564,331.1210	3999.0360	0.0000	0.9610
	BC factor	2.7740	1	2.7740	7.7730	0.0060	0.0450
BCS	Body weight	996,309.8080	2	498,154.9040	42.7830	0.0000	0.3430
	BC factor	55.5850	2	27.7930	77.8880	0.0000	0.4870
Group	Body weight	118,583.2230	1	118,583.2230	10.1840	0.0020	0.0580
	BC factor	0.2260	1	0.2260	0.6330	0.4270	0.0040
Sex	Body weight	52,287.2040	1	52,287.2040	4.4910	0.0360	0.0270
	BC factor	1.6340	1	1.6340	4.580	0.0340	0.0270
BCS*group	Body weight	1893.7120	2	946.8560	0.0810	0.9220	0.0010
	BC factor	1.3400	2	0.6700	1.8780	0.1560	0.0220
BCS*sex	Body weight	38,574.5990	2	19,287.2990	1.6560	0.1940	0.0200
	BC factor	1.5170	2	0.7590	2.1260	0.1230	0.0250
Group*sex	Body weight	11,742.9450	1	11,742.9450	1.0090	0.3170	0.0060
	BC factor	0.3560	1	0.3560	0.9970	0.3190	0.0060
BCS*group*sex	Body weight	11,229.7770	2	5614.8880	0.4820	0.6180	0.0060
	BC factor	0.1700	2	0.0850	0.2390	0.7880	0.0030
Error	Body weight	1,909,597.7180	164	11,643.8890			
	BC factor	58.5200	164	0.3570			
Total	Body weight	153,664,731.3010	176				
	BC factor	138.6150	176				
Corrected total	Body weight	3,490,490.440	175				
	BC factor	138.310	175				

Abbreviation: BCS, body condition score.
[a] $R^2 = 0.4530$ (adjusted $R^2 = 0.4160$).
[b] $R^2 = 0.5770$ (adjusted $R^2 = 0.5490$).

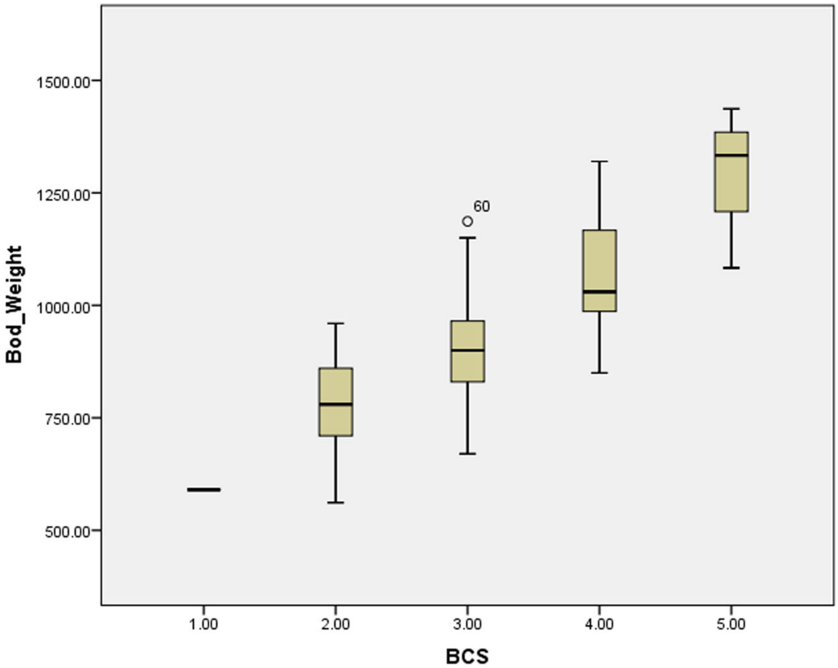

FIGURE 6 Leaf and stem plots of BCS range for body weight. BCS, body condition score.

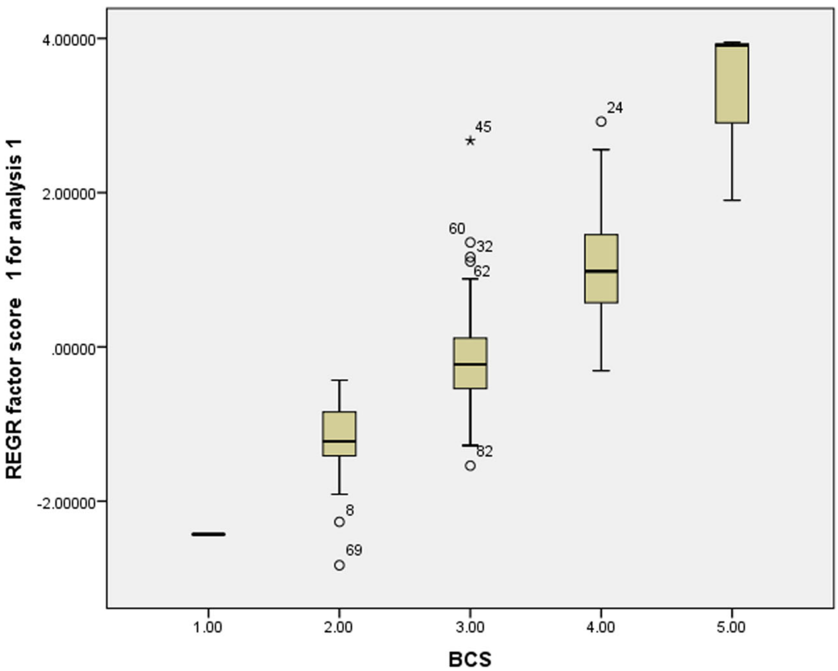

FIGURE 7 Leaf and stem plots of BCS range for body circumference factor. BCS, body condition score.

dimorphism in the greater slow loris (Anirudh et al., 2020; Nekaris & Bearder, 2011; Nekaris et al., 2020; Starr & Nekaris, 2020). Curiously, Wiens (2002) found males to be 16% heavier than nonpregnant females although head and body length did not differ, whereas O'Mara et al. (2012) reported a weak size dimorphism with females being heavier than males.

In our sample some significant differences in size were found between both sexes with regard to a number of body circumference measurements. For example, among the Sumatran group, females were significantly larger than males in terms of the stomach, hip, and thigh circumference. Among the Javan group, only stomach circumference was significantly larger in females. When all variables were combined in the PCA extracted body circumference factor, however, no significant differences for either group were found.

These large ranges and significant differences between some weight and circumference variables indicate that there are likely to be many external factors that contribute to weight variations in captive slow lorises, especially those that have been in contact with humans for a long time and require rehabilitation. Similarly, Anirudh et al. (2020) suggested that the size differences reported by O'Mara et al. (2012) may be down to the over- or underweight captive individuals featured in the study. Digestive health issues might be the causative

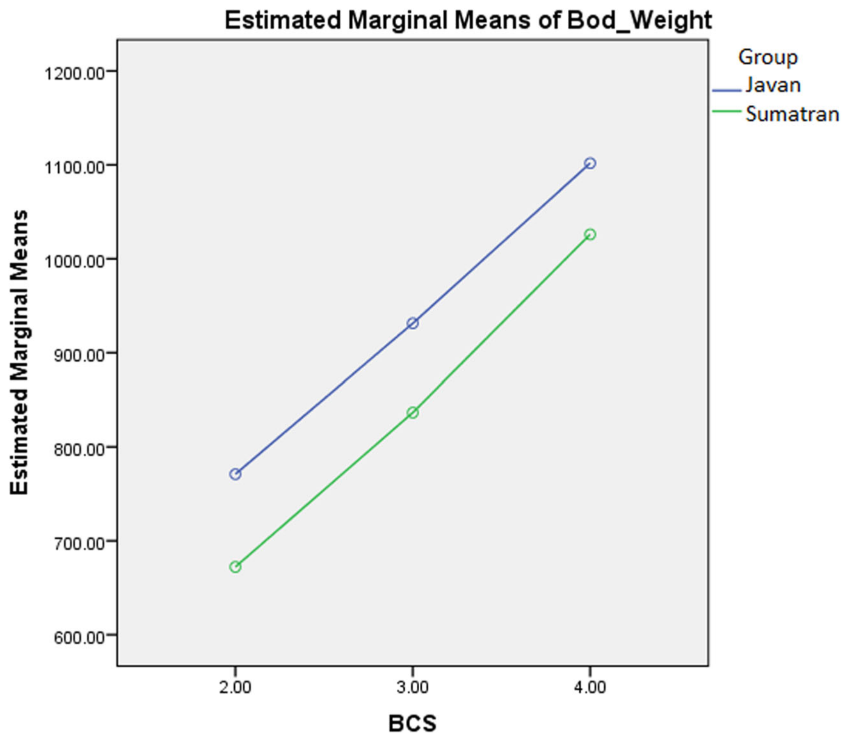

FIGURE 8 BCS categories mean for body weights. BCS, body condition score.

factor of these BCS variations. Gastrointestinal parasite manifestation inhibits nutrition absorption and compromises energetic costs (Frias et al., 2018; Rode-Margono et al., 2015). Degenerative changes in age-related cases can contribute to feeding metabolism derangement, making nutrition absorption suboptimal (Fuller et al., 2014). Excessive energy intake could affect excessive body fat accumulation (Chun et al., 2019). A greater energy intake in captivity could explain the difference in body weight between captive and wild slow lorises (Reeves et al., 2020). Excessive energy intake and lack of exercise lead to obesity in captive animals (Goodchild & Schwitzer, 2008). The obese captive slow lorises might not have the drive to exercise, which would keep them inactive and gain more weight (Bauer et al., 2012).

Body weight cannot always be associated with overall body condition because the same body weight might comprise different muscle and fat compositions (Reamer et al., 2020). Of the five components of body circumference, the hip circumference was the most significantly correlated with changes in body weight and BCS at the five levels of BCS, followed by thigh circumference and thorax circumference.

Abdominal and hip circumference indicate fat accumulation (Martin-Gimenez et al., 2017; Streicher & Reinhardt, 2020). The accumulation of fat can also be seen clearly on the torso shapes in Figure 3 on their dorsal presentation and Figure 4 on their lateral presentation. The torso circumference (thorax, abdominal, and hip) provides a more representative skeletal muscle condition than the limb circumference (arm and thigh) (Cavedon et al., 2020). Measurements of body circumference had significant results when compared to body length measurements in measuring the development of body dimensions (Turner et al., 2016). Anatomically, muscle and fat are not located in the epiphysis, but cover the diaphysis so that changes in the composition of muscle mass and therefore, fat can only be detected on the diaphysis (Betts et al., 2013; Daly et al., 2004).

BCS is a familiar and easy-to-use noninvasive semiquantitative assessment based on muscle and fat composition (Clingermann & Summers, 2012). The main feature of BCS is the scale system (Russel et al., 1969). The mid-range value on the scale describes the ideal body condition, the lower values describe thin or even emaciated, and the higher values describe or even obese body conditions (Clingermann & Summers, 2012). Subjective BCS descriptions require objective validation to reduce bias. In this study, we chose body weight and circumferences to validate the BCS development in slow lorises. Body weight and body circumference measurements have long been used as predictors of body condition (Cavedon et al., 2020; Salazar-Cuytun et al., 2020). Both methods require only simple tools to acquire measurements and do not require anesthesia.

In this study, we found that BCS had a strong effect on body measurements in both groups, even when considering both group and sex effects in body measurements. BCS explained alone nearly 25% of the variance of our model comprised of body weight and the body circumferences factor, while differences in groups explained about 18% and the difference between sex was not significant. The absence of significant results for interaction effects between BCS and group, and BCS and sex shows that there was no bias among the BCS categories in terms of sex and group differences. Neither a third-level interaction effect (BCS*group*sex) was found to be significant. The relationship between BCS and body measurements across the two groups and both sexes obtained in this study validate that BCS adequately reflects the body weight and size of slow lorises. BCS has a positive correlation with body circumference (Pérez-Flores et al., 2016). Body weight had a weaker correlation with predicting body condition (Salazar-Cuytun et al., 2020). In this study, body circumference to BCS has a stronger correlation than body weight to BCS.

Measurement or visual assessment of body circumferences is simple, cheap, noninvasive, and requires only simple tools (Cavedon et al., 2020). Body circumference has been commonly used as an anthropometric tool to assess body composition and health risks in obese individuals (Cavedon et al., 2020; Chun et al., 2019; Martin-Gimenez et al., 2018). Body circumference, which is indirectly reflected through BCS, can also be used as an alternative predictor for several diseases (Chun et al., 2019; Pinho et al., 2018; Tran et al., 2018).

This BCS development for slow lorises has been validated statistically by our study and has the potential to be used by different stakeholders to assess slow lorises in different circumstances and situations. These may include human–animal interactions in villages by members of the local communities wishing to report a slow loris, during confiscations of slow lorises from the illegal pet trade, post-release monitoring of translocated slow lorises, and at any ex-situ facilities like rescue centers and zoos.

Confiscated slow lorises arrive at rescue centers in various and often poor conditions, so a fast decision test to help prioritize emergency treatment is would be beneficial (Fuller et al., 2017). BCS can be used to assess initial first aid. BCS assessments can also help to evaluate the condition of slow lorises during post-release monitoring and identify if or when an intervention is necessary, thereby increasing the survival rate of rehabilitated slow lorises (Kenyon et al., 2014; van der Sandt, 2017).

Monitoring BCS should be done gradually for slow lorises that cannot be released due to teeth incompleteness and/or disability since they will be cared for indefinitely in the sanctuary. If a slow loris has to spend a lifetime in care at facilities such as a sanctuary, they should be afforded humane conditions and proper care for the rest of their natural lives (Baker, 2002). It is important that the animals needs are met in their enclosures by providing them with environmental and behavioral conditions and stimuli and that resemble those of their natural habitat (Guy et al., 2014).

The BCS development initiated in this study can be further replicated and refined in future studies because the methods used can be reproduced in different locations. Differences in the accuracy of measuring body weight and body circumference can also be minimized by using the same methods and tools as in this study. Therefore, further investigation of the factors causing the BCS variation, such as the teeth condition, food palatability, prevalence of gastrointestinal parasites, metabolic disease, and geriatric conditions, should be carried out in future studies. Here we propose the five categories of BCS on slow lorises (*Nycticebus* spp.) for the first time. We are confident to recommend using these BCS categories at many rehabilitation and ex-situ conservation facilities, particularly those with Javan and Sumatran slow lorises in their care.

AUTHOR CONTRIBUTIONS

Yumni K. Ghassani: Body circumference evaluation (lead); body condition assessment (equal); body weight evaluation (supporting); conceptualization (equal); data curation (lead); illustration (supporting); methodology (equal); statistical analysis (lead); visual documentation (supporting); writing original draft (equal); writing review and editing (lead). **Puji Rianti**: Designing and characterizing the study variables (supporting); methodology (equal); writing original draft (supporting); writing review and editing (supporting). **Nur P. Priambada**: Body circumference evaluation (supporting); body condition assessment (equal); body weight evaluation (lead); conceptualization (equal); data curation (supporting); methodology (equal); visual documentation (supporting); writing review and editing (supporting). **Imam Arifin**: Body circumference evaluation (supporting); body condition assessment (equal); body weight evaluation (supporting); illustration (lead); visual documentation (lead); writing review and editing (supporting). **Indri Saptorini**: Body circumference evaluation (supporting); body condition assessment (equal); body weight evaluation (supporting); data curation (supporting); writing review and editing (supporting). **Wendi Prameswari**: Conceptualization (equal); methodology (equal); writing review and editing (supporting). **Huda S. Darusman**: Designing and characterizing the study variables (lead); methodology (equal); statistical analysis (supporting); writing original draft (equal); writing review and editing (supporting).

ACKNOWLEDGMENTS

We thank the staff of Primate Rehabilitation Center of Yayasan Inisiasi Alam Rehabilitasi Indonesia, Bogor.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

Data are available on request to the authors.

ETHICS STATEMENT

All procedures were approved by the Institutional Animal Care and Use Committee (IACUC) Commission of the Primate Research Centre (PRC) of IPB University, number IPB PRC-21-E001.

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How to cite this article: Ghassani, Y. K., Rianti, P., Priambada, N. P., Arifin, I., Saptorini, I., Prameswari, W., & Darusman, H. S. (2023). Welfare assessment of slow loris (*Nycticebus* spp.) at an Indonesian primate rehabilitation center: Development and validation of body condition score. *American Journal of Primatology*, *85*, e23524. https://doi.org/10.1002/ajp.23524