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Neonatal Weight in Gibbons (*Hylobates* spp.)

THOMAS GEISSMANN[1] AND MATHIAS ORGELDINGER[2]
[1] Anthropological Institute, Zürich University, Zürich, Switzerland; [2] Zoological Garden Frankfurt/Main and Zoological Institute, Ruprecht-Karls-University, Heidelberg, Germany

Neonatal and birth weights of gibbons have mostly been reported for single individuals, and larger samples (n = 2–8) have apparently been published for only two species of gibbons (*Hylobates lar* and *H. syndactylus*). In addition, a critical examination of the few published neonatal weights of gibbons shows that several of them should not be used. Neonatal weights are here defined as weights taken on infants up to seven days old, whereas birth weights include only those taken on the day of birth. This paper presents neonatal weights for 6 representative species of gibbons (*H. lar*, *H. leucogenys*, *H. moloch*, *H. muelleri*, *H. pileatus*, *H. syndactylus*) and some of their hybrids. Most of our data stem from surviving animals that were subsequently hand-reared and include 80 infants, thus making the previously available dataset 5 times larger. Our neonatal weights fall roughly into 3 different classes: neonates of the *lar* group (about 390 g, n = 27), the *concolor* group (about 510 g, n = 7), and the siamang (about 540 g, n = 46). This grouping corresponds not only to taxonomic units within the hylobatids, but also to grouping of gibbons by adult body weight. No weight difference between males and females is evident in our sample, and hybrids of the *lar* group do not appear to differ in weight from pure species. True birth weights (i.e. weights recorded on the day of birth) are available for only a few individuals. These weights are, on average, 7% higher than neonatal weights, but the difference is not statistically significant. Additional samples of neonatal weights suggest that infants that die on the day of birth weigh, on average, 17% less, twins weigh 29% less, and infants born by Cesarean section weigh 19% more than our reference sample of neonates.

Key words: birth weight, neonatal weight, Cesarean section, neonatal death, premature birth, twins, Hylobatidae

INTRODUCTION

Reliable information on neonatal weight is of importance for allometric and ontogenetic studies [e.g., Leutenegger, 1973, 1976, 1977; Martin, 1990; Martin & MacLarnon, 1985]. This data is also of value for breeding purposes: Knowledge of neonatal weights for rare and endangered species may be very helpful in evaluation

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Address reprint request to Thomas Geissmann, Anthropological Institute, University Zürich-Irchel, Winterthurerstrasse 190, CH-8057 Zürich, Switzerland.

of new-born health and/or prematurity and to identify cases where low birth weight infants require special attention [e.g., Trum, 1972].

Neonatal weights are now available for many primate species [e.g., see review by Brizee & Dunlap, 1986], including the great apes [e.g., Brizee & Dunlap, 1986; Cousins, 1976; Fooden & Izor, 1983; Keiter, 1981]. In contrast, very few records of gibbon neonatal weights have been published. These are usually found in zoo reports and generally refer to a single individual. Apparently, no previous attempt has been made to collect and critically review these published records. This is particularly important because most reports containing more than a single neonatal weight can be shown to include questionable or even incorrect data (as will be shown below).

Eisenberg [1981, p. 487] gave 400g as (mean?) neonatal weight for lar gibbons (*Hylobates lar*), and 560g for siamangs, but the author did not mention how many individuals had been weighed. Schultz [1972] published three neonatal weights for siamangs (470g, 510g, and 530g), but these were taken on preserved specimens. Weights of preserved specimens differ from fresh body weights [e.g., Keith, 1895]. One of Schultz's neonates (male 1, Z 71) was also weighed at the Zürich Zoo, when freshly dead; its weight was then recorded as 80g lower (Schmidt, personal communication) than the weight published by Schultz [1972]. In the archive of the late Prof. A.H. Schultz (housed at the Anthropology Institute of Zürich University), one of us (TG) found a hand-written note of Schultz saying another of his specimens (female Z 54) was "poorly preserved" and that "fresh weight may have been more, since brain partly lost". Although these weights have previously been used as "fetal (birth) weight" in allometric studies [e.g., Leutenegger, 1973], they appear unreliable in the light of the evidence revealed above. A series of four siamang neonatal weights was published by LaMalfa [1969], and listed again by Fox [1977]. However, the lowest weight of 6 oz (= 170g) was a printing error and should have read 16 oz (= 454g) (Mr. S. LaMalfa, personal communication).

The present article deals with both neonatal and birth weights. Most previous publications of gibbon "birth weights" either fail to mention how old the gibbon was when it was first weighed, or explicitly state that the weight was not taken on the day of birth.

No reliable comparison among neonatal weights of the various gibbon species has been possible so far. Such comparative data would be of great value, because body weights of *adult* gibbons have been reported to vary considerably among some of the species: most gibbons of the *lar* group weigh about 5–6 kg, the crested gibbons (*concolor* group) and the hoolock (*H. hoolock*) around 7–8 kg, and the siamang (*H. syndactylus*) about 11–12 kg [Geissmann, 1993; Jungers, 1984].

For the present report, a large number of previously unpublished neonatal weights were obtained from several zoos. In addition, where possible, neonatal weights collected from the literature were critically reviewed and merged with our new samples. Part of the sample of siamang neonatal weights (n = 20) was cited in a previous report [Geissmann, 1991], but the sample has been more than doubled for the present report (n = 46).

MATERIALS AND METHODS

The sources of our main data set (80 neonatal weights of gibbons) are listed in Table I. Most of the neonatal weights collected for the present report stem from zoo animals that were subsequently hand-reared. Prematurely born individuals (if known), abortions, and all individuals known to have died on the day of birth were analyzed separately. This was done in order to minimize the bias towards lower neonatal weights introduced by pre-term births. Twin births were also excluded

TABLE I. Sources of Neonatal Weights (Including Birth Weights) of Gibbons Used in This Study*

	Number of weights			
	lar group	*concolor* group	*Hylobates syndactylus*	Total
Data from the literature [a]	12	2	2	16
Data from zoos (present study) [b]	15	5	44	64
Total	27	7	46	80

*Twins, animals from Cesarean sections, and those that died on the day of birth are excluded.
[a]Anonymous [1976]; Breznock et al. [1979]; Driechciarz and Schröpel [1987]; Gabriel [1983]; Guittin [1982]; Hutzelsider [1937]; Ibscher [1967]; Martin et al. [1979: average value of five weights]; Merz [1987]; Oosterhuis [1975]; Rumbaugh [1966, 1967a,b]; Sasaki [1963]; Sawina and Opachowa [1981]; Schmidt-Pfister [1984]; Schröpel [1982].
[b]See Acknowledgments for sources of data.

from our main sample, because twins in catarrhine primates are often born prematurely [Geissmann, 1989a]. One newborn siamang bitten to death by its mother (trying to escape from a net), one silvery gibbon (*H. moloch*) bitten in the head by the father, and one newborn siamang whose umbilical cord got entangled in the cage equipment each died on the day of birth, but were included in the analysis because the circumstances of their deaths did not indicate that they had been prematurely born.

Animals born by Cesarean section were also analyzed separately, because often the timing of these operations does not fully correspond to that of a natural term birth. The consequences of this are discussed below.

Another problem is where to set the upper age limit for animals to be included in a "neonate" sample. For instance, Schultz [1944, p. 12] reported on a "'newborn' *Hylobates lar*, weighing 411 gm. and most likely about 8 days old." This weight has been used by other authors as representing a "fetal (birth) weight" [e.g., Leutenegger, 1973]. In the present study, we excluded all weights taken from animals known to be older than 7 days. Unless otherwise noted, each individual is included only once. Repeated measurements of individuals (i.e. a small longitudinal sample of 5 siamangs which were weighed almost daily) are used only when comparing weights at different days of the neonatal period.

Traditionally, crested gibbons (i.e. the *H. concolor* group) were treated as a single species with several subspecies [Groves, 1972; Marshall & Sugardjito, 1986]. In this report, however, black crested gibbons, *H. concolor*, white-cheeked crested gibbons, *H. leucogenys*, and yellow-cheeked crested gibbons, *H. gabriellae*, are regarded as distinct species, for reasons reviewed in previous publications [Geissmann, 1989b, 1994]. The taxonomic treatment of the Hylobatidae used here follows the one proposed in Geissmann [1994].

For statistical analysis we used the statistical software StatView, version 4.02 (Abacus Concepts), with a significance level of 0.05. Statistical significance was calculated using an unpaired Student's t-test, and analysis of variance (ANOVA), with the dependent variable being the subjects' neonatal weight or birth weight. The independent variables were species (or species group) and day of weighing. The Bonferroni/Dunn post hoc analysis was used to determine which means differed significantly at the 0.05 probability level.

RESULTS AND DISCUSSION

Differences Among Species or Species Groups

Table II shows the mean neonatal weights, standard deviations and range for each species and the hybrids. As shown in the table, significant differences

(ANOVA, df = 7, $P < 0.05$) in neonatal weight were found when comparing *H. syndactylus* with each species of the *lar* group and with the hybrid sample, and between *H. lar* and the hybrids of the *concolor* group. No significant difference was found between *H. syndactylus* and the two samples of the *concolor* group, or among the samples of the *lar* group. If the comparison is carried out among species groups instead of species, two pairings show a significant difference (*lar* group vs. *H. syndactylus*, and *lar* group vs. *concolor* group (ANOVA, df = 2, $P < 0.05$); only the third pairing does not (*concolor* group vs. *H. syndactylus*). The differences among the species groups remain significant when hybrids are excluded from the comparison.

The average neonatal weight of the hybrids of the *lar* group is very similar to that of pure species of the same group, whereas that of two hybrids of the *concolor* group is relatively high. Neonatal weights of the hybrids are not significantly different from those of pure species of the same group, but this may be influenced by the small size of the hybrid samples.

Due to small sample sizes, the average weights for many of these species must be regarded as tentative approximations, especially those based on less than 10 specimens (e.g., *H. moloch*, *H. muelleri*, *H. pileatus*, and *H. leucogenys*). Nevertheless, the weights roughly fall into three different classes (Fig. 1): Gibbons of the *lar* group have a neonatal weight around 390 g (n = 27), neonates of the *concolor* group weigh about 510 g (n = 7), and siamangs are even heavier, weighing about 540 g (n = 46). These differences in neonatal weight are statistically significant (with one exception), and roughly correspond to the differences in adult body weight, which divide the gibbons into the same three groups (see Introduction). The absence of significant differences between the gibbons of the *concolor* group and *H. syndactylus* may be due to the small sample of neonatal weights of the former.

No neonatal weights are available for the species *H. agilis*, *H. klossii*, *H. conolor*, *H. gabriellae*, or *H. hoolock*. If the relationship between adult weight and neonatal weight suggested above holds true, we should expect a neonatal weight of about 390 g for both *H. agilis* and *H. klossii*, and a higher weight of about 500 g for *H. concolor*, *H. gabriellae* and *H. hoolock*. At least *H. agilis* and *H. gabriellae* are breeding with some success in captivity, and neonatal weights of these species may eventually become available to test this prediction.

None of the subsets in our main sample shows sexual differences in neonatal weight, independently of whether species or species groups are compared (unpaired Student's t-tests, $P > 0.05$). This remains true if only animals weighed on the day of birth are included in the analysis (i.e., using birth weights only, instead of neonatal weights). Gibbons do not show marked sexual dimorphism in body weight when adult [Geissmann, 1993; Jungers, 1984]. Therefore, the absence of significant sex differences in the neonatal weight or the birth weight of our gibbon samples is not unexpected.

Birth Weights

The percentage of gibbons certainly weighed on the day of birth varies among species (*H. lar*: 23%, *H. moloch*: 67%, *H. muelleri*: 33%, *H. pileatus*: 25%, *H. leucogenys*: 60%, *H. syndactylus*: 39%). Mean birth weights are shown in Table III. Birth weights of *H. syndactylus* are significantly higher than those of either *H. lar* or the *lar* group (ANOVAs, df = 5, $P < 0.05$, and df = 2, $P < 0.05$, respectively).

Figures 2a and b show the neonatal daily weight in our two largest samples: the *lar* group and *H. syndactylus* (some animals had to be excluded, because although they had been weighed during the first week, the exact day of weighing has not been

TABLE II. Neonatal Weights (g) of Gibbons †

		Sample			
Taxon		Pooled sexes	Males	Females	Statistics*
Hylobates lar	Mean	383.4	401.4	371.7	1, 2
	SD	61.1	70.9	65.5	
	Extremes	280-500	300-500	280-450	
	N	13	5	6	
H. moloch	Mean	376.0	330.0	399.0	3
	SD	39.8	–	–	
	Extremes	330-400	–	398-400	
	N	3	1	2	
H. muelleri	Mean	401.3	369.0	417.5	4
	SD	64.0	–	–	
	Extremes	360-475	–	360-475	
	N	3	1	2	
H. pileatus	Mean	400.5	385.0	405.7	5
	SD	51.6	–	61.9	
	Extremes	340-463	–	340-463	
	N	4	1	3	
lar group (inter-species hybrids)	Mean	374.8	–	374.8	6
	SD	115.1	–	115.1	
	Extremes	290-539	–	290-539	
	N	4	–	4	
lar group (without inter-species hybrids)	Mean	387.7	386.4	390.8	7, 8
	SD	54.8	59.4	57.8	
	Extremes	280-500	300-500	280-475	
	N	23	8	13	
lar group (inclusive inter-species hybrids)	Mean	385.8	386.4	387.0	
	SD	64.0	59.4	71.0	9, 10
	Extremes	280-539	300-500	280-539	
	N	27	8	17	
H. leucogenys leucogenys	Mean	480.2	475.2	500.0	
	SD	79.2	90.5	–	
	Extremes	395-567	395-567	–	
	N	5	4	1	
H. leucogenys siki x *H. gabriellae*	Mean	570.0	–	570.0	1
	SD	–	–	–	
	Extremes	560-580	–	560-580	
	N	2	–	2	
concolor group (including hybrids)	Mean	505.9	475.2	546.7	7, 9
	SD	78.3	90.5	45.3	
	Extremes	395-580	395-567	500-580	
	N	7	4	3	
H. syndactylus	Mean	536.9	536.8	537.1	2, 3, 4, 5,
	SD	70.7	78.6	62.7	6, 8, 10
	Extremes	390-685	390-685	397-650	
	N	46	24	22	

† Twins, animals from Cesarean sections and those that died on the day of birth are excluded. Abbreviations: SD = standard deviation, N = number of births.

* Comparison among species and species groups (pooled sexes) with ANOVA post hoc analysis (Bonferroni/Dunn): Significant differences occur in comparisons indicated by the same number ($P < 0.05$).

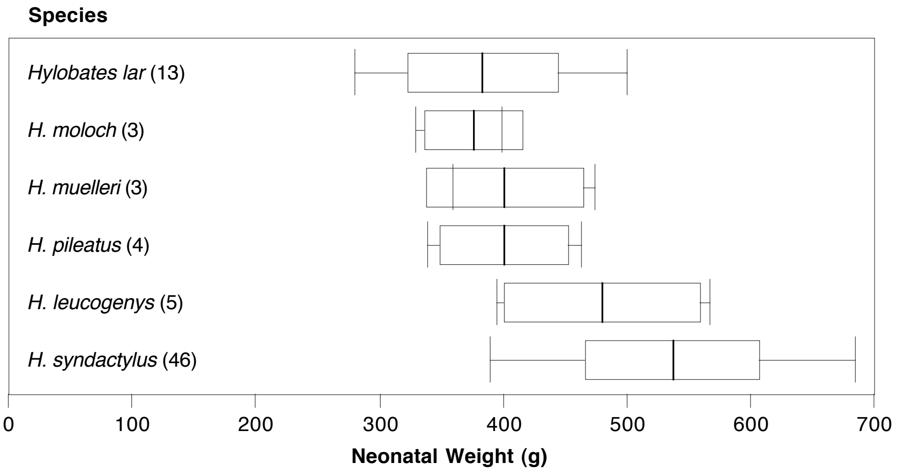

Fig. 1. Average neonatal weights (g) for 6 different gibbon species (hybrids excluded), showing standard deviations (boxes) and upper and lower limits. Sample size for each species is given in brackets.

recorded). In addition to these cross-sectional data (each individual is used only once in these samples), Figure 2c shows longitudinal growth data of 5 *H. syndactylus* (3 males and 2 females). No statistical weight difference among days was found in any of these three samples (ANOVAs, $P > 0.5$). For further analysis, we lumped the daily data of each sample into three subsets of different age: Subset 1, weighed on day 1 (birth weight); subset 2, weighed on days 2-3; subset 3, weighed on days 4–7. The 3 subsets comprised 7, 4, and 9 animals in the *lar* group, 18, 8, 9 in *H. syndactylus*, and 5, 8, 18 in the longitudinal data of *H. syndactylus*. No statistical difference among the three subsets was found in any of these groups (ANOVAs, $P > 0.5$). This also remained true when we finally lumped subsets 2 and 3, thus comparing animals weighed on day 1 with all other neonatal weights.

Most primate species (human and nonhuman) on which we have good data as well as many species of mammals other than primates lose weight during the first few days or weeks (depending on the species and exogenous factors) after birth [humans: Betke et al. 1991; Gladtke et al., 1983; Hertl, 1989; Joppich & Schulte, 1980; *Papio*: Brizzee & Dunlap, 1986; Moore & Cummins, 1979; *Macaca mulatta*: Ruppenthal, 1979; *M. nemestrina*: Sackett & Ruppenthal, 1992; Standaert et al., 1984]. A clearly defined loss of body weight is not observed in our cross-sectional data of the *lar* group, but is evident in both the cross-sectional and the longitudinal data for *H. syndactylus* (i.e. during days 2–4, and during day 3, respectively). Nevertheless, subsets of our samples weighed on different days of the neonatal period do not differ significantly among each other (see above).

Birth weights are frequently used as a life history parameter for comparative studies, but because birth weights are frequently not available, neonatal weights are sometimes used as a direct substitute. A comparison between the data in Tables II and III reveals that most birth weights are higher than neonatal weights (on average 7%, range –4% – +18%). This difference is, however, not statistically significant.

As a result, we recommend the use of our neonatal weights as provisional estimates of birth weights for the respective gibbon species, until larger samples of true birth weights become available. The sample of birth weights presented here

TABLE III. Birth Weights (g) of Gibbons †

Taxon		Sample			Statistics*
		Pooled sexes	Males	Females	
Hylobates lar	Mean	368.3	400.0	352.5	1
	SD	54.8	–	–	
	Extremes	305-400	–	305-400	
	N	3	1	2	
H. moloch	Mean	399	–	399	
	SD	–	–	–	
	Extremes	398-400	–	398-400	
	N	2	–	2	
H. muelleri	Mean	475	–	475	
	SD	–	–	–	
	Extremes	–	–	–	
	N	1	–	1	
H. pileatus	Mean	463	–	463	
	SD	–	–	–	
	Extremes	–	–	–	
	N	1	–	1	
lar group	Mean	405.9	400.0	406.8	2
	SD	55.4	–	60.6	
	Extremes	305-475	–	305-475	
	N	7	1	6	
H. leucogenys leucogenys	Mean	487.3	481.0	500.0	
	SD	86.7	–	–	
	Extremes	395-567	395-567	–	
	N	3	2	1	
H. syndactylus	Mean	551.4	554.8	548.0	1, 2
	SD	87.5	98.9	80.3	
	Extremes	390-685	390-685	406-650	
	N	18	9	9	

† Twins, animals from Cesarean sections and those that died on the day of birth are excluded. Abbreviations: SD = standard deviation, N = number of births.
* Comparison among species and species groups (pooled sexes) with ANOVA post hoc analysis (Bonferroni/Dunn): Significant differences occur in comparisons indicated by the same number ($P < 0.05$).

appears to be reasonably large only in the case of *H. syndactylus* (n = 18) and for this species is probably more reliable than the estimate provided by the sample of neonatal weights.

Special Samples

In a hand-reared pair of siamang twins born at Los Angeles Zoo (male: 367 g, female: 396 g), the individual birth weights are about 29% lower than neonatal weight in single births (536.9 g) and about 31% lower than birth weight in single births (551.4 g). In both comparisons, the difference is statistically significant (Student's t-test, df = 46, $P < 0.004$, and df = 18, $P = 0.015$).

Singletons that are stillborn or die on the day of birth (*H. muelleri*: 365.0 g, n = 2; *H. pileatus:* 379.7 g, SD = 42.6, n = 3; *lar* group hybrids: 334.0 g, n = 2; *H. leucogenys*: 390.0 g, n = 1; *concolor* group hybrids: 422.0 g, n = 2; *H. syndactylus*: 354.3 g, SD = 162.5, n = 7) tend to have lower weights than those surviving the day of birth, irrespective of whether they are compared to neonatal or birth weights. Gibbons which do not survive the day of birth weigh about 17% (range 5–34%)

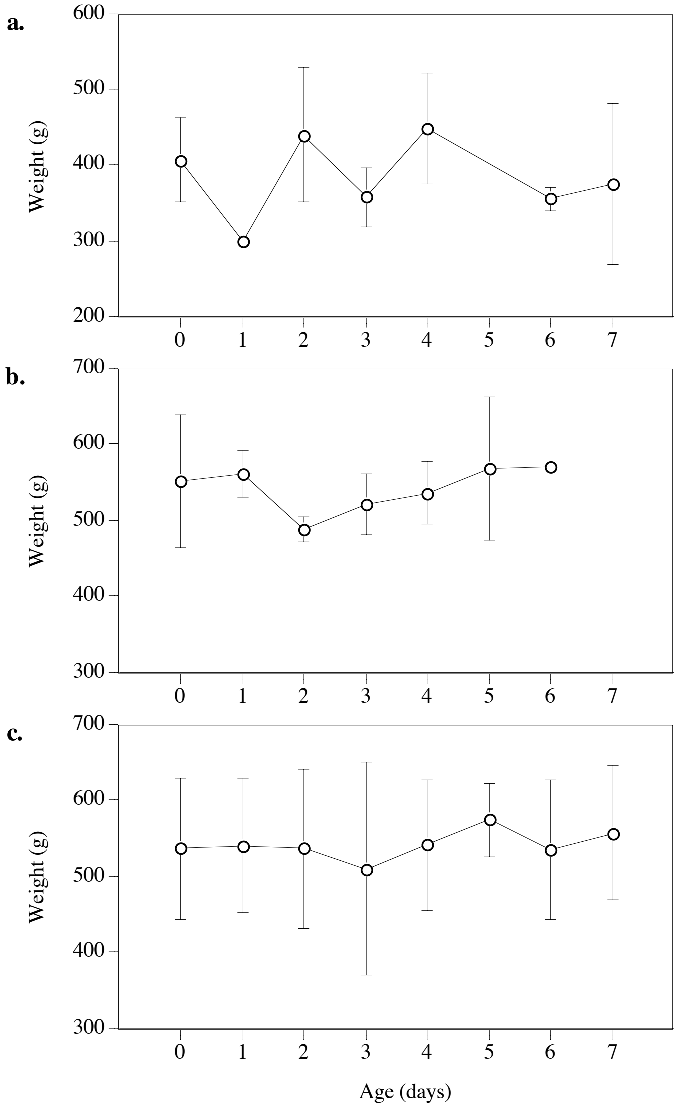

Fig. 2. Average weights (g) of gibbons during each day of the neonatal period: **a:** gibbons of the lar group (n = 20, including hybrids); **b:** *H. syndactylus* (n = 35); **c:** *H. syndactylus*, longitudinal data (n = 5). Each individual is used only once in samples a and b.

less than the corresponding sample of neonatal weights, and about 24% (range 18–36%) less than the corresponding sample of birth weights. The difference is statistically significant for *H. syndactylus* (Student's t-tests; vs. neonatal weights: df = 51, $P < 0.0001$; vs. birth weights: df=23, $P = 0.0006$). Our sample of neonatal deaths contains at least some animals which were identified as premature births during morphological examination, and probably several other prematurely born infants which were not recognized as such.

Infants born by Cesarean section tend to have elevated birth weights (*H. lar*: 500 g, n = 1; *H. moloch*: 418 g, n = 2; *H. muelleri*: 466.2 g, SD = 54.1, n = 4) in comparison with either neonatal weights (about 19% on average, range 11–30%) or with birth weights (about 13%, range –2 – +36%), but the difference is not statistically significant in within-species comparisons (Student's t-tests; $P > 0.05$). It is significant, however, if the data for the *lar* group are pooled (Student's t-test; vs. neonatal weights: df = 31, $P < 0.01$). Cesarean sections are frequently carried out after parturitional problems in a female have become apparent, i.e., some time after the date on which a term birth should have occurred [e.g., Ritscher, 1980; Ritscher & Linke, 1982]. This probably accounts for the elevated birth weight of these animals.

Data From the Literature

Although the neonatal and birth weights published in the present report are similar to some of the previously published data for lar gibbons and siamangs, other published data differ markedly from ours. The reason for this difference is not always clear. For instance the "birth weight of gibbons (440-450 g for 8 infants)" reported by Breznock et al. [1979] for *H. lar* is much higher than either our neonatal weights or our birth weights for either *H. lar* or for gibbons of the whole *lar* group. The "mean birth weight" of 503 g reported by Schultz [1972] for siamangs is considerably lower than both the neonatal and birth weights reported here. This may at least in part be due to the incomplete preservation of one of Schultz's three specimens (see Introduction).

CONCLUSIONS

1. Neonatal weights of gibbons fall roughly into 3 classes which correspond in increasing order to groupings by adult body weight, the *lar* group, the *concolor* group, and the siamang.
2. A critical examination of the few published neonatal weights of gibbons shows that several of them should not be used.
3. No significant weight difference between males and females occurs in this sample.
4. Data on true birth weight are insufficient to draw any conclusions about the relation to neonatal weight.
5. Additional samples of neonatal weights suggest that twins and infants which die on the day of birth weigh less, and infants born by Cesarean section weigh more than our reference sample of neonates.

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