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BRIEF REPORTS

Macaca thibetana at Mt. Emei, China: I. A Cross-Sectional Study of Growth and Development

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Six free-ranging groups of *Macaca thibetana* were studied at Mt. Emei, in southwest China. Patterns of growth and development observed during the study are described for this species for the first time. Data were collected mainly during the birth season of 1986. Food handouts made possible the measurement of body weight and sitting height. Changes in fur color and growth of forehead hair were noted. Dark hair appeared on the broad white forehead of infants at the end of the third month. A triangular patch formed about 30 days later, and full cover developed within 4.5 to 5 months. For the first 1 or 2 weeks, the fur was blackish; it then became yellow, and by the age of 3.5–4.5 months, it was brown or blackish, i.e., adult color. Growth data on body weight and sitting height for different age-sex classes were collected. For adult males, body weight was 18 kg, sitting height (SH) 55 cm, and ponderal index 33. For adult female, body weight was 13 kg, sitting height 47 cm, and ponderal index 27. Females were considered to be adult at age 5 years.

Key words: *Macaca thibetana*, growth, forehead hair, pelage color, body weight, sitting height

INTRODUCTION

The natural history of *Macaca thibetana* is poorly known. Based on information of varying reliability, ranging from short surveys to anecdotal reports by local people, Fooden et al. [1985] summarized the status of knowledge up to that time. To better understand this unique and intriguing Chinese primate, a long-term field project was initiated at Mt. Emei, in southwest China. The project began near the end of 1984 and continues to the present.

The first step was estimating the ages of animals. Most of the criteria used to estimate age in captive primates cannot be used in the field. Body weight and trunk length have been ingeniously acquired for a group of Japanese monkeys [Mori, 1979]. A suspended scale also has been used for weighing animals [Eisenberg, 1981]. The following age markers were helpful in this study: 1) the color transition of fur from the typical natal to the adult and the course of forehead hair growth; and 2) birth of the first infant to a female.

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Figure 1

Macaca thibetana has been long confused with *M. arctoides* because of similarity in dorsal color, size, and tail length. However, they are recognized as separate species mainly on the basis of marked differences in features of the genitalia [Fooden, 1980, 1983; Fooden et al., 1985]. The name *Macaca speciosa* has been applied to both *M. arctoides* and *M. thibetana* [Chen et al., 1985; Ye et al., 1985]. Data on growth and development of *M. thibetana* may provide new information to support Fooden's macaque classification.

METHODS

Study Site and Subjects

Data were collected mainly during a 3-month field study during the 1986 birth season, from March 7 to June 15. Data on the age of primiparous females also were collected during the mating season of 1987, from September to December.

Six groups of *M. thibetana* range at an altitude between 1,260–2,100 m on the northeast slope of Mt. Emei, which rises between 475–3,099 m above sea level. Most of the animals spend considerable time feeding around the trail, not avoiding people, and many have developed begging or robbing behavior. Sometimes monkeys attack tourists for food. People feed the monkeys for pleasure, to ensure their own safety, or as an offering to Buddha. In the present study, all members of group A, the main group whose social behavior was studied, were recognized individually by an investigator who had observed the animals for about 300 hours before the study period began. Each group, except F, was observed once every 2 or 3 days, for about 6 hours a week. Group F was less frequently observed. Thus, conditions were good for observation and taking measurements.

Fur Color and Growth of Forehead Hair

Twelve of 32 infants were born before the observers arrived at the study site. Eleven newborns were first seen within 1 week after birth, four with attached umbilical cords about 30 cm long. Fortunately, growth stages of forehead hair could be noted in the infants that were born in the first half of March or before. Because changes in fur color were very subtle, it was difficult to determine precisely the onset of changes. If a 4- or 5-day-old infant was not observed for 1 week or longer, a noticeable change in fur color could be observed to have taken place. A second change occurred at the age of 3.5–4.5 months.

Measurement of Body Weight

A body scale (RC-1) (for humans) was used to obtain body weights. This equipment at first did not appear to be suitable for precise measuring; however, fortunately, after testing the scale with a known 2-kg weight, readings of 1.9 kg were routinely reproduced, indicating that the scale was indeed usable. The animals were attracted with a favorite food (peanuts) to sit or stand on the scale (Fig. 1a); thus, 39 males and 41 females were weighed between April 15 and May 13. In order to avoid duplicate measurements of the same individuals in groups B–E, an animal's external characteristics were noted as carefully as possible when its weight was taken. As mentioned above, identification of members of group A was not a problem. Because animals in Group F avoided people somewhat, attempts to weigh monkeys from this group were not successful. If an animal was weighed more than once, an average was taken as its weight.

Fig. 1. The measurements of body weight (BW) and sitting height (SH) of *Macaca thibetana* at Mt. Emei. The animals were attracted by peanuts. **A:** Bipedally standing on the scale; **B:** Quadrupedally standing on a tree trunk to which a 50-cm reference length was marked with a white rope; **C, D:** Bipedally standing on the ground (a 20-cm reference length was used).

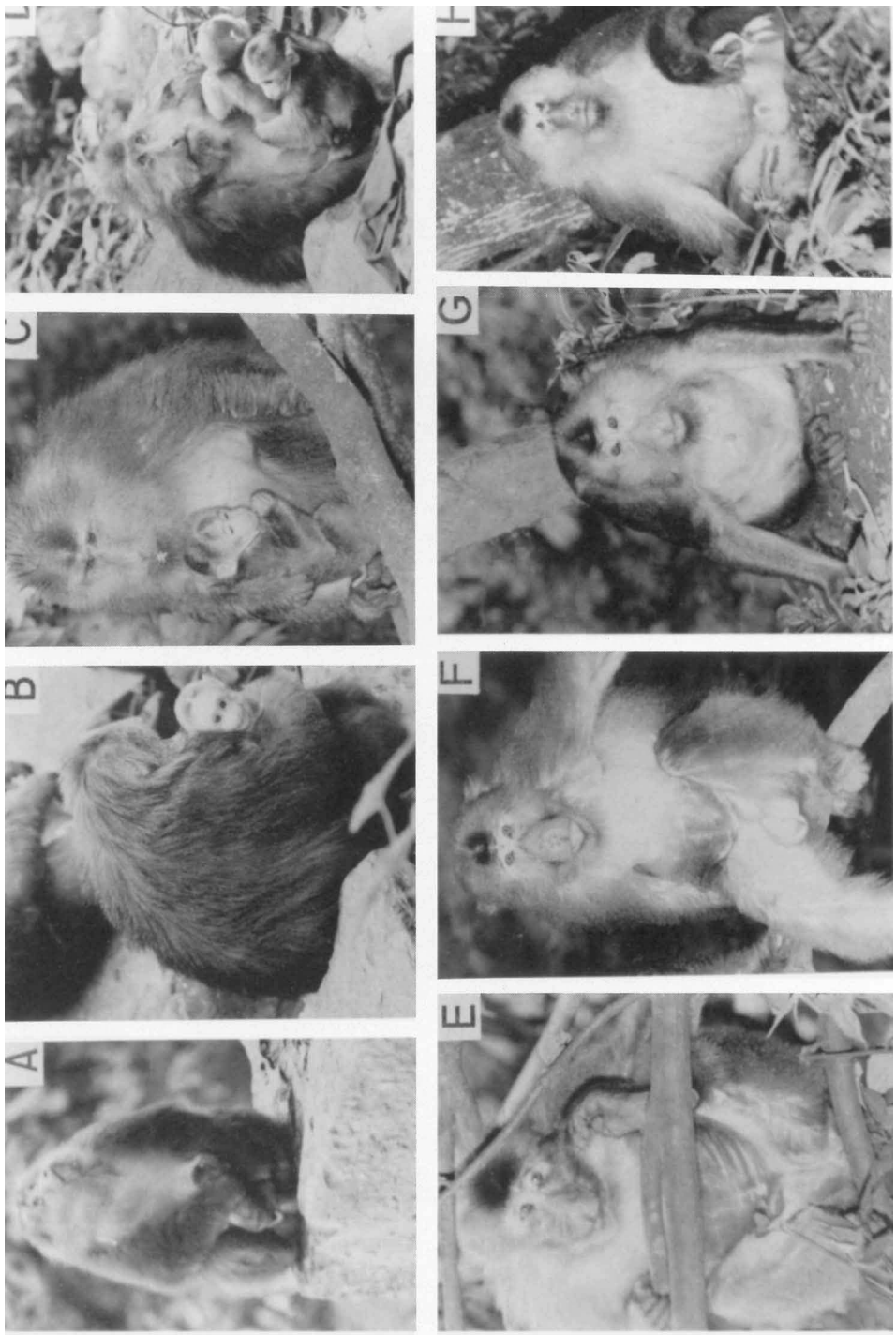

Figure 2

TABLE I. Forehead Hair Growth in *M. thibetana* at Mt. Emei (1986)

Infant[a]	Birth date	Beginning of growth	Triangle (½ area)	Full cover
cs	March 8	June 8		
gr	March 6	June 7		
wh		April 10	May 7	June 10 (about 90% cover)
he		April 19	May 17	June 13
bi			April 3	April 29

[a]cs, female, the second oldest infant in group C; gr, male, the youngest in group A; wh, male, the third oldest in group A; he, female, the second oldest in group A; bi, female, the oldest in group A.

Measurement of Sitting Height

Sitting height was defined as the distance from the highest point of the head in the midsagittal plane to the most caudal point on the ischial callosities [Sirianni and Swindler, 1985]. Measurement was done with the animal standing quadrupedally (Fig. 1b) or standing bipedally (Fig. 1c, d). The researcher held peanuts in one hand, which were shown to the monkey to attract the animal either into position on a dead tree trunk, where a white rope was fastened to indicate a 50 cm reference length, near a steel tape, or near a 20-cm rope hanging from the researcher's other hand. Various reference lengths served as "surveyor's rod" on film. Photographs were taken from at least 5 m using a 70–210 mm zoom lens. The camera was nearly perpendicular to the plane formed by the animal's body axis and the reference measure. The primary source of measurement error with this method resulted from deviation of the camera from the correct position. With 15 degrees' deviation (the maximum possible) and a distance of 50 cm between hanging rope and monkey (the maximum distance), the maximum error in measurement was determined to be less than 10%. Compared with the possible error resulting from an animal's body posture (the trunk was somewhat curved), a 10% measurement error was considered acceptable. Measurements of sitting height for 95 individuals were compiled from 120 35-mm black-and-white frames, which were placed under a binocular microscope; in this way, the relative length of the known-length measurement and the animal's sitting height were determined.

Determining Age at Onset of Adulthood

Only three individually recognized primiparous females (two in group A, one in group F) were available for estimating age at first birth; the animals were recognized from 1984 or 1985 and gave birth at the age of 5 years during the 1987 birth season. Under field conditions, we preferred to use the practical definition of an adult female; that is, a female who has given birth to at least one infant, is often seen carrying an infant, and has elongated, often pendulous nipples as a consequence of suckling [Eisenberg, 1981]. Combining information on the age and size of primiparous females (as an anchor) with the measured size data on different age-sex individ-

Fig. 2. The ontogeny of forehead hair and change in fur color in *Macaca thibetana* at Mt. Emei. **A:** The blackish fur of a 2-day-old newborn (named gr, in group A); **B:** Bare, white broad forehead of gr, at the age of 81 days; **C:** The brown hair triangle appears at the age of 4 months (in group E); **D:** Two infants of group A, with different fur colors: the front one (bi) bore its adult color at the age 5 months, whereas the infant in the back bore a yellow-colored fur (this second infant was gr, and this picture was taken on the same day as B); **E:** A 3-year-old female; **F:** A subadult male; **G:** An adult female; **H:** An adult male.

TABLE II. Body Weight (BW) and Sitting Height (SH) of *M. thibetana* at Different Age Classes*

Age range (yr)	Males				Females			
	Mean BW (kg) ± SD with range	n	Mean SH (cm) ± SD with range	n	Mean BW (kg) ± SD with range	n	Mean SH (cm) ± SD with range	n
0.02[a]	0.7		18.1		0.7		18.1	
0.9–1.2	2.5 ± 0.1	5	27.1 ± 1.5	7	2.3 ± 0.2	4	26.5 ± 1.4	5
	2.4–2.7		24.9–28.8		2.0–2.4		24.8–28.6	
1.9–2.2	4.2 ± 0.5	9	32.5 ± 2.4	8	4.1 ± 0.4	8	31.8 ± 0.8	5
	3.5–5.0		29.5–36.4		3.5–4.7		31.1–33.3	
2.9–3.2	5.8 ± 1.3	5	35.8 ± 2.9	10	5.4 ± 1.0	7	36.9 ± 5.3	7
	5.0–8.0		29.7–39.0		4.8–7.5		30.8–45.6	
4–5	10.4 ± 1.4	4	40.7 ± 1.1	9	8.0 ± 0.9	5	40.9 ± 6.2	9
	9.0–12.0		39.4–42.9		7.0–9.0		32.9–49.1	
6–7 (M), >5(F)	15.0 ± 1.5	4	47.5 ± 2.8	3	12.8 ± 1.8	17	46.9 ± 5.3	14
	13.0–16.5		40.0–50.0		9.7–15.0		37.5–52.4	
>7(M)	18.3 ± 2.4	12	55.0 ± 4.8	17				
	14–21.5		47.1–63.2					

*Measurements were done from April 15 to May 13, 1986, for BW, and from May 9 to May 18 for SH. The age ranges of 1–3 years are based on birth seasonality in 1986. Adults (A), >5 years for females, >7 years for males; subadult males (SA), 6–7 years.

[a]Data processing needs a numerical age here. The newborn's weight, 0.7 kg, was calculated from the mean weight of adult females [Leutenegger, 1973], and the sitting height of 18.1 cm, was derived from one measurement photograph. It was assumed that male and female newborns have the same SH.

TABLE III. Ponderal Indexes of *M. thibetana**

Age (yr)	Male	Female
0.02	3.9	3.9
1	9.2	8.7
2	12.9	12.9
3	16.2	14.6
4–5	25.6	19.6
6–7	31.6 (SA)	27.3 (A)
>7	33.3 (A)	

*See Table II for the A and the SA.

TABLE IV. Linear Relationship Between Body Weight (BW) and Sitting Height (SH) in *M. thibetana* at Mt. Emei

Sex	Regression equation	Std. error of est.	r	Std. error of RC	T	DF	Probability (<)
Female	$BW = -7.901 + 0.401SH$	1.468	0.953	0.063	6.322	4	0.004
	$BW^{1/3} = 0.002 + 0.049SH$	0.040	0.998	0.002	28.353	4	0.001
Male	$BW = -10.932 + 0.520SH$	1.674	0.973	0.055	9.434	5	0.001
	$BW^{1/3} = 0.022 + 0.050SH$	0.092	0.991	0.003	16.482	5	0.001

TABLE V. Regression Formula of Age Prediction and Statistics in *M. thibetana* at Mt. Emei*

Sex	Regression equation	Std. Error of Est.	r (or R)
Female	$LgY = -10.187 + 0.734SH - 0.017SH^2 + 1.263\times10^{-4}SH^3$	0.097 (SH), 2.739×10^{-3} (SH^2) 2.477×10^{-5} (SH^3)	0.959
	$Y = 0.523 + 0.425BW$	0.022	0.952
Male	$Y = -5.077 + 0.233SH$	0.010	0.956
	$Y = 0.339 + 0.410BW$	0.016	0.974

*In the calculation, 6 years was used as the age at which the females reached the end of somatic growth; 8 years was used for the males.

uals made it possible to estimate growth. A male the size of an average adult female is probably fairly close in size to a smaller primiparous female at the time of her first birth. The age at which a female completes her somatic growth is probably a year later than her age at first giving birth [Eisenberg, 1981]. Based on the principle that "adult sexual dimorphism must be the result of the greater growth time available to males" [Gavan & Swindler, 1966], the age at which males complete growth can be estimated. The term "subadult" is used for males. Subadults are characterized by size (smaller than adult males and larger than or equal with adult females), incomplete development of secondary sexual characters and testes [Eisenberg, 1981], and social behavior; all the subadult males were low-ranking, tended to be peripheral, and had little opportunity to mate with adult females.

RESULTS

Changes in Fur Color and Growth of Forehead Hair

No quantitative data could be gathered to describe changes in dorsal fur color, but a general description can be summarized as follows: coat color at birth, blackish with silveriness; age at first color change, 1 or 2 weeks; first color, yellow; color after 3.5 months (adult color), brownish or blackish (Fig 2).

Combining data from five infants, growth of forehead hair appeared to have its own special timetable (Table I). Within the first 3 months, the forehead of infants was broad and not visibly different from a bare white face; the grayish or brown hair then began to appear along both sides of the midforehead. Two weeks later, the hair grew into the shape of an inverted "V" and 2 weeks later a central triangle of hair covered half of the forehead. Another 3 to 5 weeks were needed to complete full cover, when gaps at the top and sides between new hair growth and other hair disappeared last.

Somatic Growth

Because of long-term environmental stability, variation in the natural food supply over the years should be small (unpublished data), which would tend to accentuate differences among growing animals born in different years. Births were fairly well synchronized, and the body sizes of most individuals of a given birth season were fairly close. Therefore, it was not difficult to distinguish between juveniles 1 to 3 years old. Because of cumulative effects of individual differences in growth rates, older age classes were not as easy to demarcate as young juveniles. To reduce errors in estimation, two age classes were used: 4–5 years for both sexes and 6–7 years for males. Females typically first gave birth at age 5 years, and the end of somatic growth was 1 year later. The 6- to 7-year-old males were classified as

subadults. They weighed an average of 15 kg, which was just between the mean weights of 18.3 kg for adult males and 12.8 kg for adult females. The average sitting height of subadult males was also intermediate between adult males and adult females. The testes of subadult males were smaller than those of adult males. Data on somatic growth are summarized in Table II. The lower limit of adult female weights (Table II) was 9.7 kg, which was 76% of 12.8 kg, the mean weight of adult females.

Body sizes of members of group A, the highest ranging group in the slope-ranging population, seemed to be greater than those of the members of the lower-ranging groups, with mean weights for nine adults at 21.0 kg for males (n = 3) and 14.3 kg for females (n = 6). In the lower-ranging groups, average weights were only 17.4 kg for males (n = 9) and 12.0 kg for females (n = 11). The other age-sex classes showed the same tendency. Two of the four subadults were in group A, and the mean weight of these two was 15.9 kg, heavier than the weights of some adult males in lower groups. This difference in weights should be examined in future investigations.

A ponderal index, mean weight (kg) × 100/mean sitting height (cm), has been used to describe the changes in form of both sexes in various species [Gavan, 1953; Van Wagenen & Catchpole, 1956]. The ponderal indices for *M. thibetana* are shown in Table III. Information on the relationship between body weight and sitting height is shown in Table IV.

Estimation of age was one of the goals of this study. To provide a quick estimate of age, using weight or sitting height and/or its transformations as the independent variable(s) and age or Log (age) as the dependent variable, the regression formula of age prediction, the standard error of estimation, and r (or R for two or more independent variables) are presented in Table V. Note in particular that the standard error of estimation was very low (<0.1) and that the r or R values were significantly high (>0.95, $P < 0.0001$).

DISCUSSION

The ontogeny of forehead hair in *M. thibetana* is interesting and may be one of several species-specific characteristics. The schedule of forehead hair growth may be used for rough estimates of age of 5-month-old infants. The newborn's black fur color (and color change) is quite different from that of *M. arctoides* [Bertrand, 1969; Chevalier-Skolnikoff, 1974].

The heavier average weight of the highest ranging group (A) may be a specific adaptation to the relatively cooler habitat, given that intergroup transfer of males has resulted in small genetic distances between groups [Nozawa et al., 1975]. This phenomenon is similar to that found in a troop of Japanese monkeys in an area of heavy snowfall [Watanabe, 1975]. Of course, more work should be done over several years to increase the sample size.

Most monkeys at the study site did not avoid people, but some were very cautious and could not be measured. In particular, adult males chased yearlings away from the scale and the investigator. As a result, sample sizes for some age-sex classes were small, and sampling biases were unavoidable. Another problem inherent in this kind of cross-sectional study was determining the exact number of years to reach adult size. A working hypothesis could be formed regarding age of full growth for males and females based on the age of three primiparous females individually recognized from 1984 or 1985.

In well-regulated and successful monkey breeding colonies, longitudinal studies are desirable for establishing velocity curves. In colonies, however, conditions for normal growth are difficult to simulate. Our approach seems a more suitable model for the feral animal's growth study under the unique condition. Among the merits

of cross-sectional studies of wild populations are the following: 1) the animal develops under natural conditions; and 2) the work can be done quickly and less expensively than under captive conditions. The conditions at Mt. Emei are good for field studies; however, as indicated, without the data on the other macaque species gathered by previous investigators, the interpretations offered here would be questionable.

The average age at the onset of adulthood of five species of macaques in captivity is 4 years, with a maximum error of 0.5 year, including *Macaca mulatta, M. fuscata, M. radiata, M. nemestrina,* and *M. fascicularis* [Drickamer, 1974]. Note in particular that body weights of the macaques are much different. According to some long-term field data, currently published estimates of age at onset of adulthood in wild primates are probably considerably underestimated, particularly among the Cercopithecinae. Wild female toque macaques and baboons experience first birth at about 6 years of age, which is about 2 years later than those raised in captivity [Eisenberg, 1981; Altmann et al., 1977]. This is also true for a troop of Japanese monkeys at Koshima [Mori, 1979]. The age of onset of adulthood (about 4.5 years) of *M. thibetana* in this study was close to that of macaques in captivity, which may result from the special situation in which food handouts, as extra nutrition, are available to these wild monkeys from April to October, when natural resources are also rich, although food resources are poor during the rest of the year.

In addition, the size of females at the time of first conception seems constant [Eisenberg, 1981; Mori, 1979]: about 77% of the average weight of adult females of three troops of Japanese macaques in comparable conditions. The 77% is calculated from data published by Mori [1979] and Watanabe [1975]. Interestingly, our results show the same tendency: the lightest adult female weighed 9.7 kg, 76% of 12.8 kg, the mean weight.

The ponderal index and body weight of *M. thibetana* are probably the largest in macaques. The male index tended to be higher than that of females; for animals older than 2 years, this difference became increasingly obvious. The growth pattern is almost the same as in rhesus monkeys [Van Wagenen & Catchpole, 1956], but it is quite different from that seen in chimpanzees and in humans [Gavan, 1953; Harrison et al., 1964].

CONCLUSIONS

1. Dark hair appeared on the broad white forehead of *M. thibetana* infants at the end of the 3rd month. A triangle formed about a month later, and full cover occurred by about 5 months. Fur color within the first 1 or 2 weeks was blackish; it then became yellow, and at the age of about 4 months, it changed to brown or blackish, the adult color.

2. For adult males, the average weight was 18 kg, sitting height 55 cm, and ponderal index 33. For adult females, average weight was 13 kg, sitting height 47 cm, and ponderal index 27.

3. The age of onset of first conception in females was 4.5 years, with first births occurring at the age of 5 years. Using that age as an anchor, the endpoint of growth was estimated as 6 years for females and 8 years for males.

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