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ONTOGENY AND GROWTH OF HIGHER PRIMATES – A SOMATOMETRIC APPROACH

ABSTRACT: The studies on non-human primate growth and somatic development are still relatively rare, and there is no comprehensive longitudinal study. The methodical problems in this type of primate research seems to be the most important reason for this. Despite the effort to integrate research into anthropology and primatology, anthropological and primatological research is not sufficiently interconnected. The persistence of marked differences in methods and methodology in both disciplines of ontogenetic research is probably the cause of this. Numerous anthropological, biomedical and evolutionary studies have compared man and primates, including their ontogeny. However, there is no consistent framework for such comparative studies. Both human and non-human primate ontogeny have numerous specific as well as common features, but they are not defined by comparable quantitative data. The research project entitled "Complex study of postnatal ontogeny of higher primates – basic adaptive processes, social structure, and sexual dimorphism", co-ordinated by Václav Vančata (Grant Agency of the Czech Republic – grant project No. 206/93/1029), is the first part of a longitudinal study of higher primate ontogeny which should yield representative data on primate ontogeny. The main subject of the study is a captive group of Macaca mulatta living in the Primate Center of VÚFB Konárovice. Currently, there is a population of 169 macaques living in 8 groups with a semi-natural (aged) multimale social structure. New groups are created after weaning at approx. 4–8 months of life. Three groups of macaques (73 individuals) have been included in the longitudinal complex study to date. The measuring is done by Helena Zlámalová, who is the author of a modification of the standard anthropometric procedures for primates. Some modifications are very specific, and the technique of measuring is different from that of analogical anthropometric measurements in man. Standardisation of the position of the body and individual segments was the first and main task of using somatometry methods in primates. We have measured 48 metrical traits: body mass, body height, sitting height, 9 dimensions of the head, and 15 traits of the upper limbs, 12 of the lower limbs and 9 of the trunk. Body height has never been measured in non-human primates, but is very important for the description of the linearity of the primate body and also for comparison of the ontogeny of non-human primates and man. The cross-sectional shape of the chest has been described by kyrtometry. This study should create a basic framework for future comparative studies of monkeys and man. The main goal of this contribution is to demonstrate the methods and their use in practice, and to indicate the future prospects of somatometry in research into primate ontogeny. The first complete results of a pilot study on the somatic development of rhesus macaques up to the maturation period are analysed. At present we have sufficient data from a longitudinal study of three groups of Macaca mulatta, which enable us to describe the somatic development of macaques up to three years of age. We can analyse not only the development of body size but also of individual body segments. The first results of an analysis of the ontogeny of the chest crossection will be presented. One of the most important tasks of the pilot study, the application of the modified anthropometric method in primate research, has been fulfilled: modified somatometry of macaques seems to have great value for the description of growth and sexual differentiation. The sample group, measured up to 40 months of age, proves the methods to be reliable and confidently precise. Some specific measurements like body height appear to be very important for comparative studies of the ontogeny of body size and proportions in man and non-human primates. The period of measurement seems to be sufficient and representative.

KEY WORDS: Ontogeny – Growth – Somatometry – Macaca mulatta – Longitudinal study

INTRODUCTION

Studies on primate body parameters and primate growth (Gavan and Hutchinson, 1973; Hamada, 1982, 1994; Hamada et al., 1986; Jebavý and Jebavý, 1993; Spiegel, 1985; van Wagenen and Catchpole, 1956; Zlámalová et al., 1994) are still rather rare, and there are no unified methods enabling a comparison of results and exchange of information on body parameters of various primate populations and species. This was the reason why our research group succeeded in its application for the research project *"Complex study of postnatal ontogeny of higher primates – basic adaptive process, social structure, and sexual dimorphism"*, co-ordinated by Václav Vančata (Grant Agency of the Czech Republic – grant project No. 206/93/1029). This is the first part of a longitudinal study on higher primate ontogeny that should yield representative data on primate ontogeny.

The main results should be as follows: basic data and knowledge on the species studied, revision and modification of methods, recommendations for study of primate evolution and ontogeny, a comparative growth study of primates and man, primate reproduction and breeding, medical treatment and experimental work with primates, and primate welfare. On the basis of the above-mentioned facts, research on the formation of ontogenetic differences among individual groups of primates and man, as complex research on the differentiation processes in individual stages of ontogeny in the given primate groups, could be made possible by the results of our project.

The following specific problems are studied:

1) Growth parameters in *Macaca mulatta* (body mass, body size, basic proportions and growth indicators like skeletal age, dental age, basic hormonal indication, basic biochemical and blood parameters, etc.) will be studied together with the ontogeny of basic patterns of locomotion and behavior in relation to reproduction, social structure and environmental factors;

2) Sexual differences in ontogeny, the meaning of critical periods in ontogeny and environmental influence on the adaptive potential of a given group and individuals;

3) Application of anthropological, especially somatometric, methods to the non-human primates, improvement and modification of the method for the practical use in primatology and biomedical research, callibration of methods for comparative analysis of macaques and man and creation of a basic referential system that will make possible efficient and precise comparison of man and non-human primates;

4) Establishment of basic criteria for the comparison of the ontogeny of non-human primates and man, including defining the possibilities of parallelisation of basic ontogenetic phases in man and individual primate groups and species.

The project consists of four research studies. The study entitled "Growth and somatic development of rhesus macaques", co-ordinated by Helena Zlámalová, is based on use of modified somatometrical methods broadly used in anthropology. This contribution deals with the postnatal ontogeny of *Macaca mulatta* up to 36 months. Results of ontogenetic development of the selected somatic parameters are presented. However, the main goal of this paper is to demonstrate the methods and their use in practice, and to indicate the future prospects of somatometry in research into primate ontogeny.

MATERIAL AND METHODS

Our paper summarizes the results of a longitudinal study of several groups of *Macaca mulatta* living at the Konárovice Primate Center. Three groups of rhesus macaques have been studied, a total of 73 individuals born in Konárovice in the years 1991–1994. The animals have been studied since weaning, i.e. since their 4th to 8th months. Measuring is initially conducted at two week intervals, later at one month intervals and, finally, after two years of age, at two months intervals. Several hand-reared individuals have been studied since their birth.

The measuring is done by one person, Helena Zlámalová, who is the author of a modification of the standard anthropometrical procedure for primates. Some modifications are very specific and the technique of measuring is different compared with analogical anthropometric measurements in man. Examination is made in a special room, not in the cage, and the animals are confined but not narcotized.

Standardization of the position of the body and individual segments was the first and main task of using somatometry methods in primates. Two technical assistants are necessary for keeping the monkey in standard position and for fixing the monkey.

45 metrical traits are measured: body mass, body height, sitting height, 9 dimensions of the head, and 15 traits of the upper limbs, 12 of the lower limbs and 9 of the trunk. Body mass is measured with a precision of 10 grams; measurements were taken by tape measure with a precision of 5 mm, by a spreading caliper (cephalometer) with a precision of 2 mm and by a sliding caliper with a precision of 1 mm.

It should be stressed that, in order to maintain sufficient precision of measurement and quality of results, the following principles should be respected:

1. The measurements must be made, if possible, by one person to decrease the risk of individual error during the making of measurements.

2. The same tools must be used for the measuring, in order to exclude error caused by the differing precision of various tools. Even tools made by the same manufacturer should be verified to avoid potential differences in their scales.

3. The animals must be fixed in the standard position recommended for a given type of measuring, e.g. extended leg, flexed arm, abducted tail. Determining the most proper

standard position for the given type of measurement was quite complicated, and verification took a long time.

4. If it is safe and possible, we are recommend measuring without narcotization. There is no distortion caused by low tonus of muscles, and the values of such measurements are consistently comparable, e.g. with anthropometric data.

The data were analyzed for individuals, for each group separately and for the whole sample. Because of the low number of observations in some age categories, a monthly interval was used for the analysis.

Examples of the taking of measurements and the fixation of the animal are shown in *Figures 1 and 2.*

Head measurements

All 9 measurements of the head must be made using the standard fixation of the head (neck fixation by hands) and the trunk must be in a vertical position. Head measurements are measured by a sliding caliper, spreading caliper and tape measure. Head circumference is measured horizontally through the glabella, i.e. in the most prominent place above the nose origin *(Figure 3).*

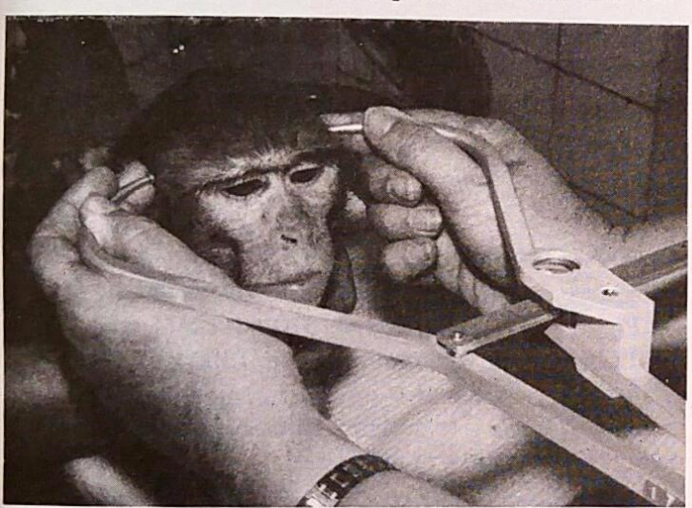


FIGURE 1. Fixation of animal. Taking of measurement of head breadth.

FIGURE 2. Fixation of animal.Taking of measurement of body height using monkey-meter.

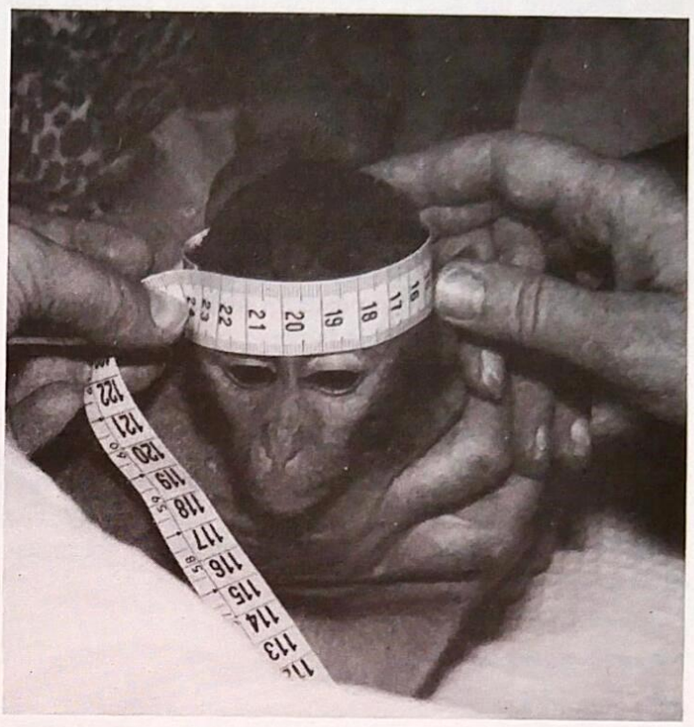


FIGURE 3. Fixation of animal. Taking of measurement of head circumference.

Body mass

This is measured with a precision of 10 grams at a moment when the animal is still (not moving).

Body height and sitting height

Height measurements, i.e. body height and sitting height, are conducted using a specially constructed monkey-meter (analogous to static anthropometer) with a precision of 5 mm *(Figure 2).*

In the case of body height, the monkey is fixed from the ventral side at six points: under the neck, in the abdominal region, in the knee region and in the ankle region. The knees must be pressed to the table top to achieve maximal leg extension. Fixing in the ankle region ensures that the monkey will stay on foot in full contact. This position is unnatural for macaques, but it is the only way of measuring this linear dimension of the body, comparable to that of man. We tried to measure the overall body length in lying position, but this was extraordinarily complicated and not very precise. A well-coordinated team can take this measurement in a few seconds, with quite good precision.

Sitting height is the distance between the ischial callosities and the upper most part of the head (vertex). Sitting with extended legs is not fully natural. For precision of measurement, it is necessary to take care that the occipital region, scapulas and gluteal region are in full contact with the table top.

Trunk measurements

Length, breadth and circumferential measurements are made on the trunk. Chest circumference is measured at the level of the nipples with slightly abducted limbs. We also measure the shape, cross-section and saggital and transversal dimension of the chest. These are measured by kyrtograph. The kyrtograph makes it possible to study changes of the shape of the chest during early ontogeny. It is a plastic wire integrated with two special fasteners. This combination enables us to make a replica of shape of chest. The results of the kyrtographic study have not yet been prepared for publication. Two individual kyrtographs are presented in *Figure 4.* There is a marked trend toward prolongation of the antero-posterior diameter of the chest during early ontogeny. This is contrary to the condition normal for human ontogeny.

Upper limb and lower limb measurements

Limb measurements are measured by tape measure and sliding caliper exclusively on the right side of body. The animal is fixed on the left side. Circumferences are measured on extended limbs *(Figure 5).*

FIGURE 5. Fixation of animal. Taking of upper limb circumference

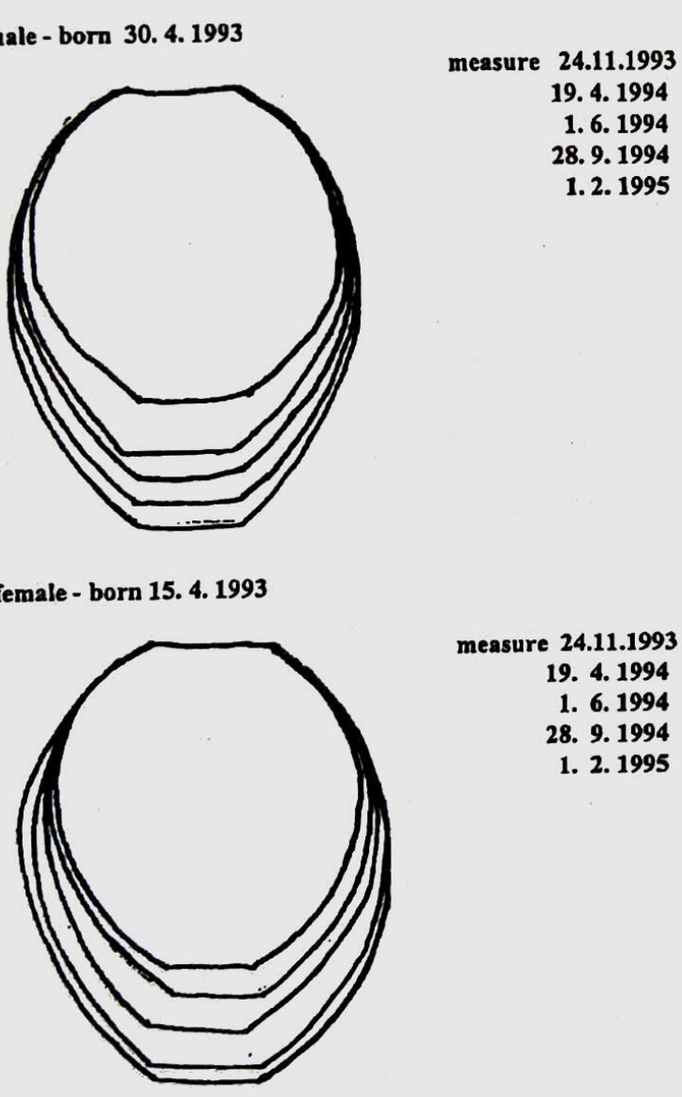


FIGURE 4. Individual development of changes of shape of the chest.

RESULTS

Body Mass *(Figure 6)*

Body mass increases basically linearly, as can be seen in the *Figure 6.* It is, on average, 520 g for males and 437 g for females in the first month of life, 1300 g for males and 1234 g for females at 6 months of age, and 1850 g in males and 1825 g in females at one year of age. Body mass is about 2500 g in males and 2400 g in females at 18 months of age. After this period, where the values are much higher in males, the period begins where the values of body mass converge. The average values in males and females are about 2790 g, and there is the same trend in succeeding age groups – about 3500 g at 30 months and 3900 g at 36 months.

Body Height *(Figure 7)*

Changes of body height are almost linear after nine months of age. Height is about 450 mm at six months, 520 mm at one year, 580 mm at one and half years and about 620 mm for males and females at two years of age. Sexual differences are not significant. After the second year the difference in body height increases, and become higher in females. It appears that there is a higher growth acceleration in females in this period, which corresponds with the analogical pre-pubertal period in man, where the start of puberty is earlier in girls than in boys. This is very considerable in terms of more rapid body growth.

Sitting Height *(Figure 8)*

Sitting height is an important feature of the evaluation of body proportion changes. In the absolute values we can see that this feature has the very same growth tendency as does body height. The values in males and females are

FIGURE 6. Development of body mass in *Macaca mulatta.*

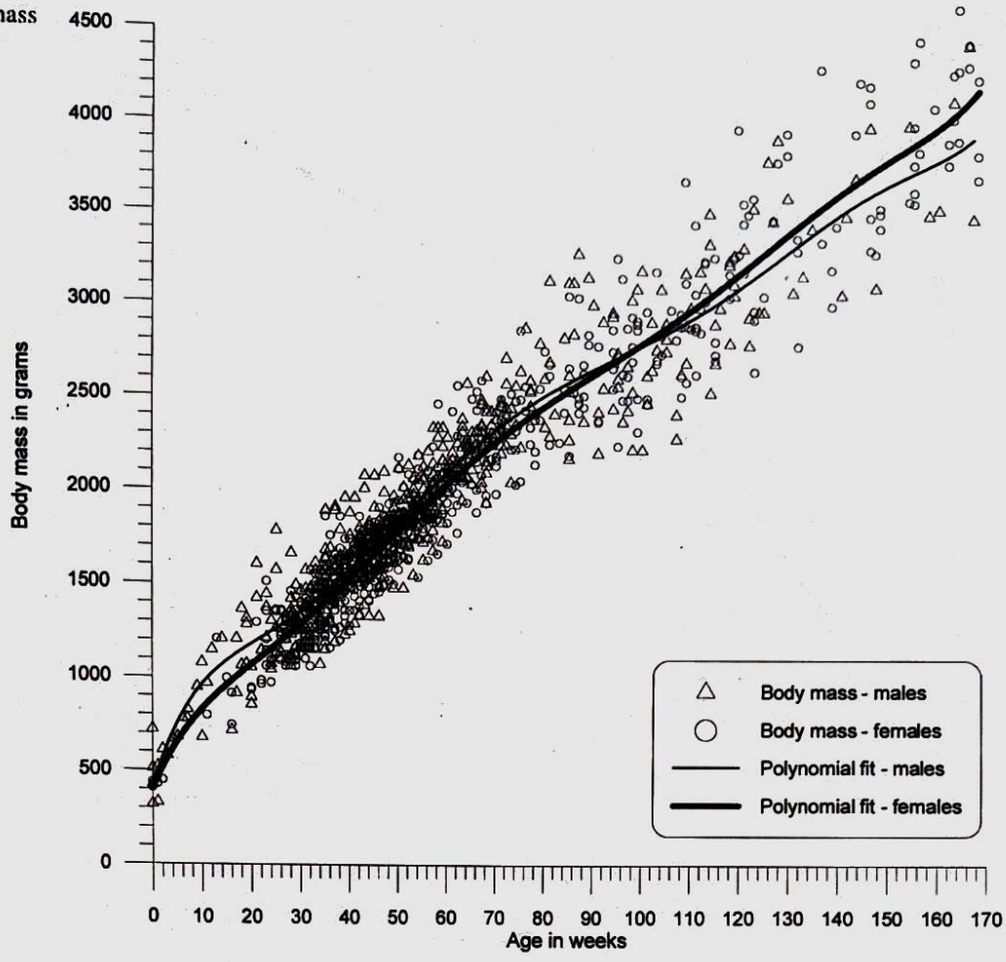
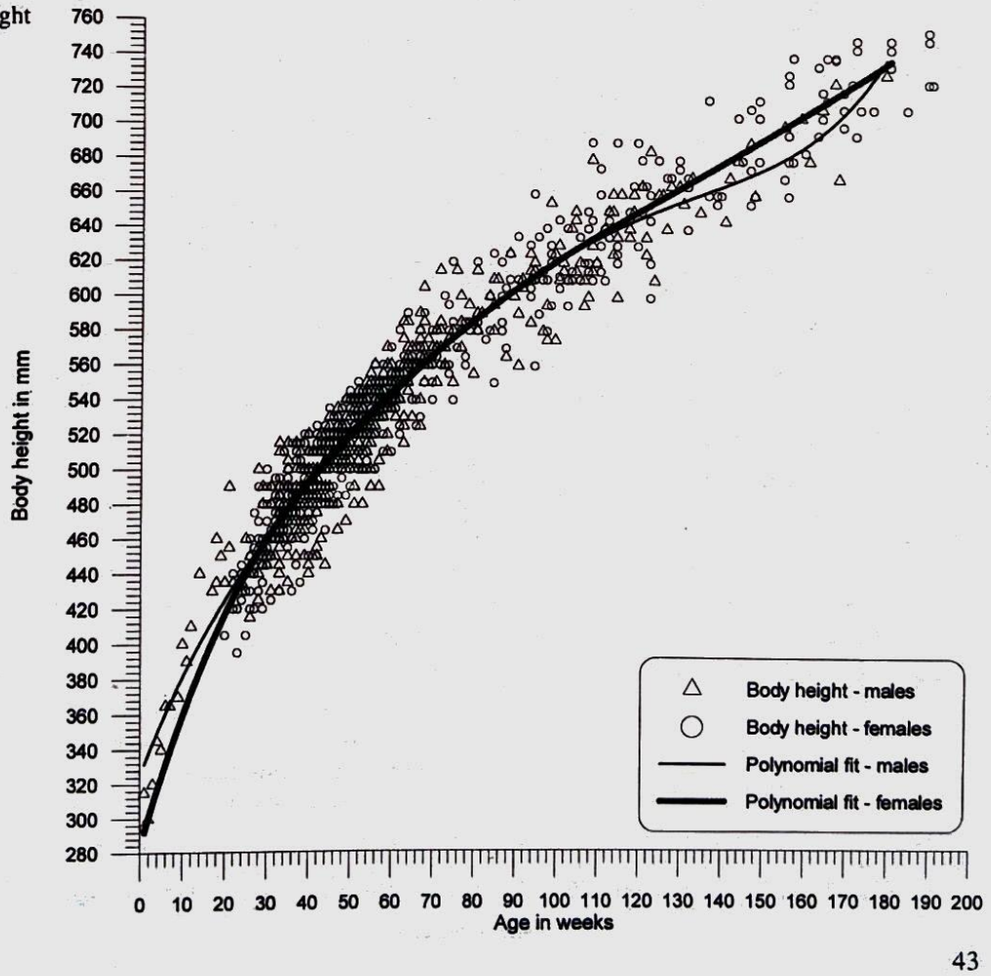


FIGURE 7. Development of body height in *Macaca mulatta.*



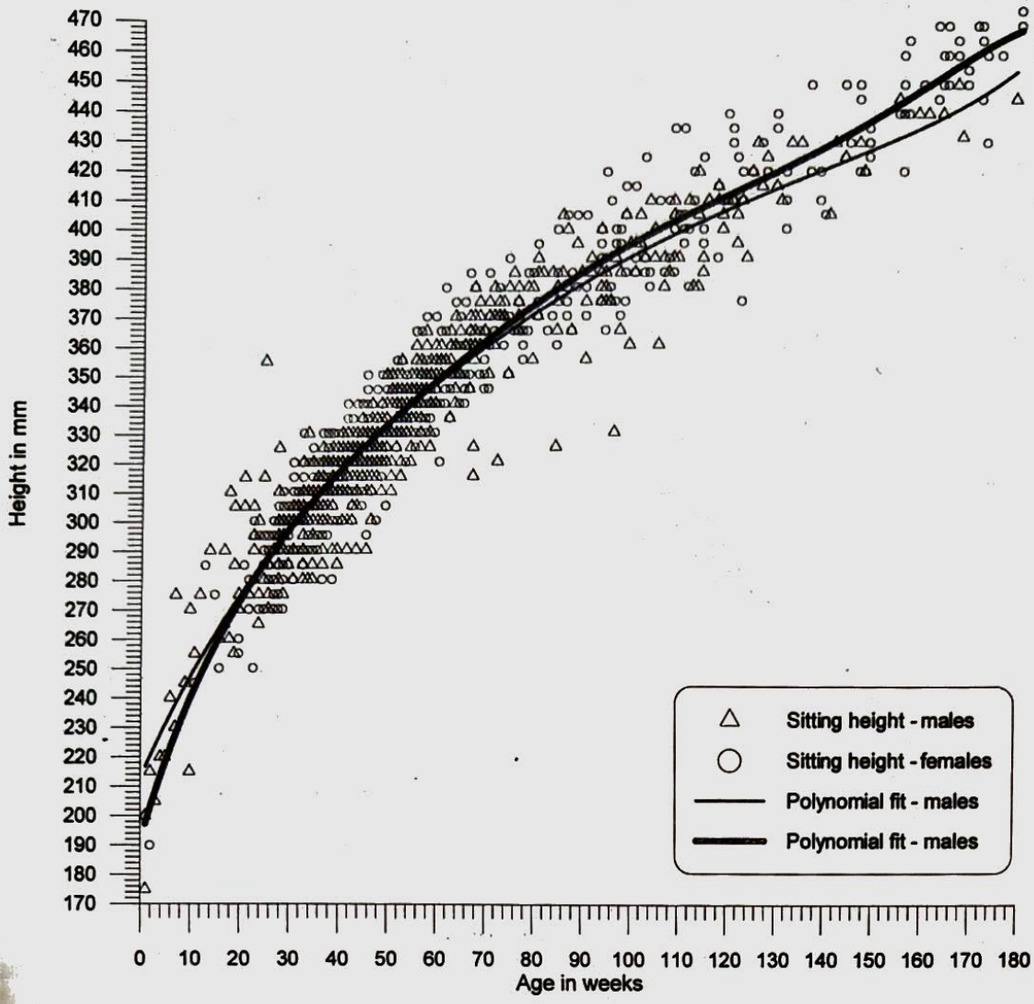


FIGURE 8. Development of sitting height in *Macaca mulatta*.

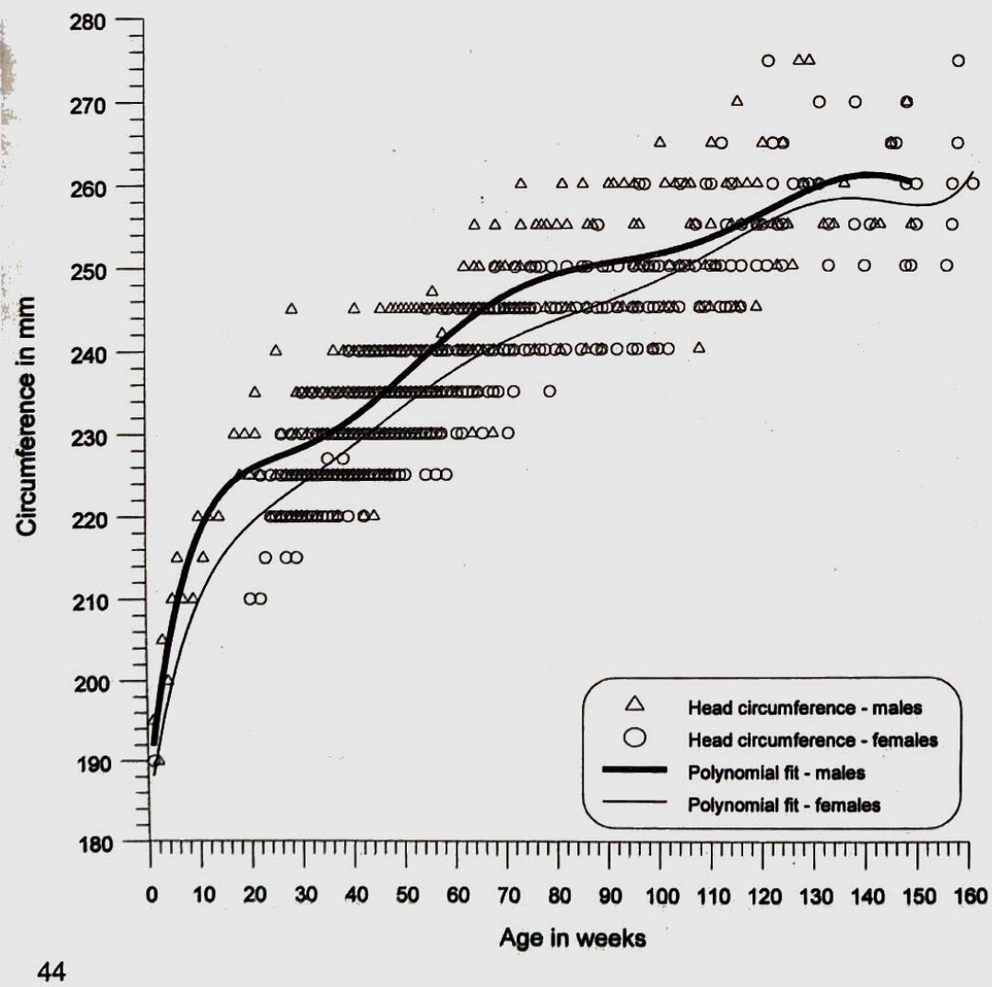
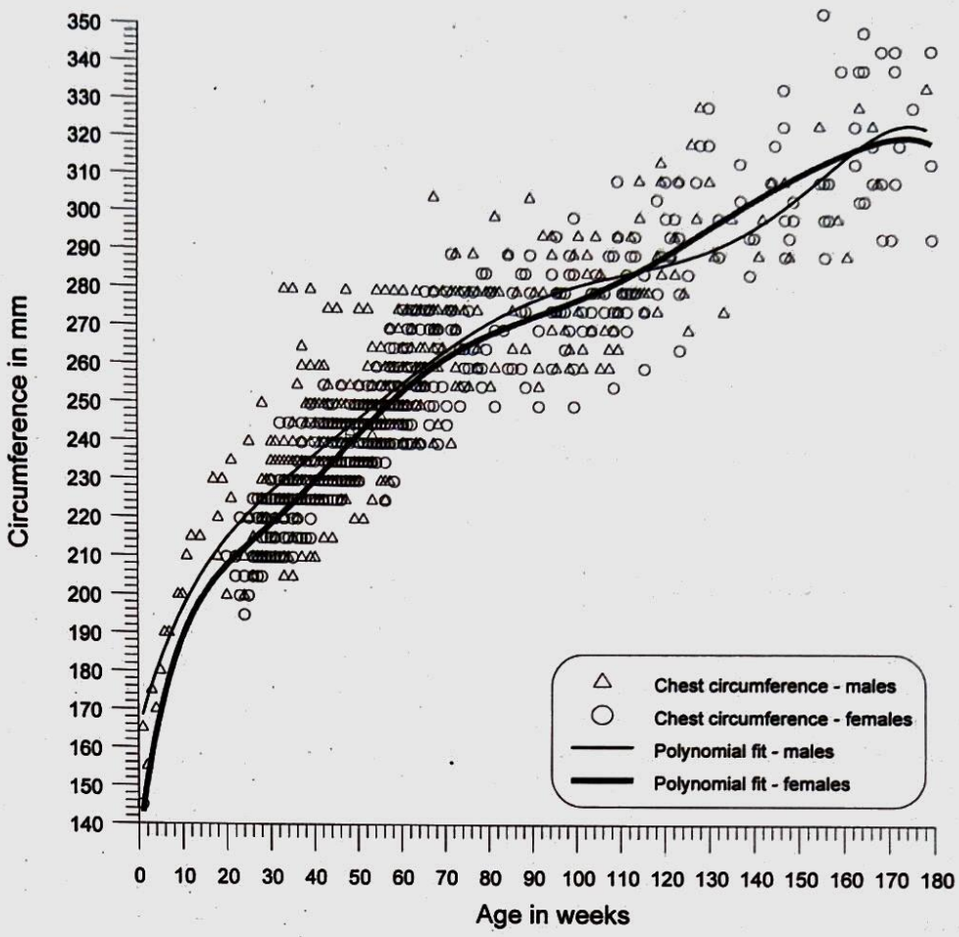


FIGURE 9. Development of head circumference in *Macaca mulatta*.

FIGURE 10. Development of chest circumference in *Macaca mulatta*.



basically the same until two years of age. A more marked growth acceleration in females can be found after the second year of life.

Head Circumference *(Figure 9)*

Head circumference shows a regular increment of values in this period, and the values are in every case slightly higher in males than in females. The velocity of increase becomes slower at three years of life. This tendency remarkably recalls the situation in man, where the head basically stops its growth at six years of age. However, the number of individuals studied is not very large, and generalization of the results would be premature. Head circumferences do not increase linearly, and there is a high sexual dimorphism in this feature.

Chest Circumference *(Figure 10)*

Chest circumference is 222 mm in males and 214 mm in females at six months, 245 mm in males and 243 mm in females at one year of age, and 273 mm in males and 267 mm in females at one and half years of age. After the second year of life there are, in all cases, markedly higher values of chest circumference in females, which also confirms our hypotheses on earlier sexual maturation in females. Chest circumference increases with age more or less linearly. There is a high sexual dimorphism in chest circumference, with the exception of the age of two years, when the degree of sexual dimorphism decreases but the value is higher for females than for males.

Arm Span

Arm span is an important parameter that informs us about the body proportions. The average values show regular increase during the early ontogeny, and they are again significantly higher in females than in males after two years of age. If we compare the values of arm span with that of body height, it follows that the values of arm span are significantly higher than those of body height, which is much more considerable after two years of life. This phenomenon is typical for cercopithecoid monkeys, and the opposite of the situation in man.

Anterior pelvic diameter

Anterior pelvic diameter is the last parameter to be presented in our paper. Naturally, there is considerable growth of the anterior pelvic diameter during the whole course of the early ontogeny we studied, and the values are in all cases higher in females. It is evident that, as in man, the anterior pelvic diameter is an important feature from the point of view of sexual dimorphism. There is a marked growth of the pelvis during three years of life, from approximately 30 mm in newborns to 70 mm at three years of life.

CONCLUSIONS

A modified somatometry of macaques seems to have great value for the description of their growth and sexual differ-

entiation (Vančata et al., 1995; Zlámalová et al., 1994, 1995). The sample group measured up to 36 months of age proves the methods to be reliable and confidently precise. Naturally, precision of measuring depends on the specificity of a measurement and the quality of the fixation of a monkey. Some specific measurements like body height are very important for the comparative studies of the ontogeny of body size and proportions in man and non-human primates. The period of measurement seems to be sufficient and representative. More frequent measurement of infants is not acceptable from the point of view of the macaque's well-being. A one month interval is acceptable for an analysis up to three years of age, but the number of observations of marginal categories is still relatively low.

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