

Age of Epiphyseal Closure in Tamarins and Marmosets

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Estimates of the chronological age for animals of unknown age provide useful information for medical, demographic, and evolutionary studies. Skeletal development, as indicated by epiphyseal closure, can be used to estimate an animal's chronological age or specify its stage of development. Many studies of Primate skeletal development have used animals of unknown age, with the order of epiphyseal closure providing a relative age for each animal. This study examines the age of epiphyseal closure at 22 epiphyseal sites using animals of known age at death in three calitrichid species (*Saguinus fuscicollis*, *Saguinus oedipus*, and *Callithrix jacchus*). The observed average age of epiphyseal closure is similar in these tamarins and marmosets. There is a significant difference in rate of development between the species. Regression equations can predict the age of unknown animals to within 4.8 months for *S. fuscicollis*, 8.6 months for *S. oedipus*, and 7.6 months for *C. jacchus* (twice the standard error of the estimate). These age estimates allow us to determine if an animal is relatively mature or immature, but are largely unacceptable for studies in which precise age estimates are necessary. The order of epiphyseal closure is similar across 11 monkey species (using additional data from published literature) and supports the suggestion of a general pattern in Primate skeletal development. *Am. J. Primatol.* 41:129–139, 1997. © 1997 Wiley-Liss, Inc.

Key words: epiphyses; tamarins; marmosets; age estimation

INTRODUCTION

Knowledge of an animal's age is important for many types of investigations, including studies of disease, reproduction, population age structure, and physical growth and development. An animal's date of birth and age may be known for captive born animals. However, for animals that are wild-born and imported or accessioned from the wild for museum collections, the date of birth is unknown

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and their age must therefore be estimated. Skeletal development, as indicated by closure of epiphyses, has been studied in many primates, including apes [Randall, 1943], cercopithecoid monkeys [Washburn, 1943; van Wagenen and Asling, 1958; Gisler et al., 1960; Bramblett, 1969; Wintheiser et al., 1977; Cheverud, 1981], squirrel monkeys [Tappen and Severson, 1971], and tamarins and marmosets [Chase and Cooper, 1969; Tappen and Severson, 1971; Glassman, 1983; Schulte et al., 1983; Nasser-Montoya et al., 1992]. Many of these studies used wild-caught animals of unknown age, and have been restricted to describing the order of epiphyseal closure. The order of epiphyseal closure allows estimating the relative age of individual animals. Animals with a greater number of closed epiphyses are older than those with fewer closed epiphyses; however, chronological ages remain unknown. Previous studies also suffer from relatively small sample sizes, and variability in developmental stages may not be well represented. Studies that included animals of known age include X-ray studies by van Wagenen and Asling [1958] and Gisler et al. [1960], a body dimension study by Gavan and Hutchinson [1973], an epiphyseal study by Cheverud [1981] on *Macaca mulatta*, a dental and epiphyseal study by Glassman [1983] on *Saguinus fuscicollis*, and X-ray studies by Schulte et al. [1983] and Nasser-Montoya et al. [1992] on *Callithrix jacchus*.

In this paper we determine the ages of closure of 22 epiphyses in samples of three New World monkey species of known age, *Saguinus fuscicollis* (saddle-back tamarins), *Saguinus oedipus* (cotton-top tamarins), and *Callithrix jacchus* (common marmosets). We compare the relative rates of epiphyseal closure in the three species, and determine how accurately age can be predicted based on the known sequence of epiphyseal closure. We also compare epiphyseal closure order observed in these monkeys to published data on epiphyseal closure in monkeys.

MATERIALS AND METHODS

The cross-sectional skeletal sample used in this study was obtained from the Oak Ridge Associated Universities Marmoset Research Facility and the Department of Anthropology at the University of Tennessee. All animals were of known age, and only individuals without observable skeletal disorders were included in this study. The animals were not used in any experimental procedures, and they died of natural causes. Standard water maceration techniques were used to clean the skeletons. The sample sizes by body region (cranial data only, postcranial data only, or both cranial and postcranial data) of individuals under 3 years of age for each species are presented by age in Table I. This includes cranial data from 40 *S. fuscicollis*, 58 *S. oedipus*, and 35 *C. jacchus*, and postcranial data from 36 *S. fuscicollis*, 67 *S. oedipus*, and 43 *C. jacchus*. A total of 423 *Saguinus fuscicollis*, 443 *Saguinus oedipus*, and 148 *Callithrix jacchus* skeletons were observed from this collection (including individuals of unknown age). The distribution of individuals by age is presented in Table II. Several subspecies of *S. fuscicollis* are present in the sample, including 30 *S.f. illigeri*, 4 *S.f. nigrifrons*, and 5 *S.f. lagonotus*. The sample also includes 2 hybrids between *S.f. illigeri* and

TABLE I. Sample Size by Skeletal Region

	Cranial data	Postcranial data	Both cranial and postcranial
<i>S. fuscicollis</i>	14	10	26
<i>S. oedipus</i>	0	9	58
<i>C. jacchus</i>	0	8	35

TABLE II. Sample Size by Age^a

Age (in years)	<i>S. fuscicollis</i>		<i>S. oedius</i>		<i>C. jacchus</i>	
	Cran	Post	Cran	Post	Cran	Post
0.0–0.09	0	0	0	0	0	0
0.1–0.19	0	0	0	0	0	0
0.2–0.29	2	4	1	3	0	0
0.3–0.39	0	1	4	6	0	0
0.4–0.49	0	0	0	0	0	0
0.5–0.59	0	3	2	2	3	3
0.6–0.69	1	2	1	1	3	3
0.7–0.79	4	2	4	4	3	3
0.8–0.89	1	1	3	3	4	4
0.9–0.99	3	0	1	1	2	2
1.0–1.09	1	0	4	4	3	3
1.1–1.19	1	0	2	2	3	5
1.2–1.29	1	0	4	4	3	3
1.3–1.39	3	4	0	0	0	0
1.4–1.49	2	1	2	2	1	2
1.5–1.59	1	1	1	1	1	1
1.6–1.69	4	3	3	4	1	1
1.7–1.79	2	1	2	2	0	0
1.8–1.89	6	4	0	0	3	4
1.9–1.99	1	1	3	3	0	0
2.0–2.09	2	1	3	3	1	1
2.1–2.19	1	1	2	3	0	0
2.2–2.29	0	0	1	1	0	2
2.3–2.39	1	1	2	3	0	1
2.4–2.49	1	1	2	2	0	0
2.5–2.59	0	0	2	2	0	0
2.6–2.69	1	1	3	3	0	1
2.7–2.79	0	1	4	4	1	1
2.8–2.89	0	1	1	3	1	1
2.9–2.99	1	1	1	1	2	2
Total	40	36	58	67	35	43
Over 3.0	147	137	141	156	75	87

^aCran, cranial; Post, postcranial.

S.f. nigrifrons, 5 hybrids between *S.f. illigeri* and *S.f. lagonotus*, and 4 hybrids between *S.f. illigeri* and *S.f. leucogenys*. All *S. fuscicollis* subspecies and hybrids were included within the *S. fuscicollis* analysis. Part of the *S. fuscicollis* sample was used by Glassman [1983] in a similar study of tamarin epiphyseal closure.

Twenty-two epiphyseal centers in the long bones, the innominate, the sacrum, the scapula, and the base of the skull were examined in all individuals to assess their degree of maturity (Table III). Epiphyses from the right side of the body were scored whenever possible. Both males and females were included. Each epiphysis was scored as open, 0, if the epiphysis was completely open, or closed, 1, if the epiphysis and diaphysis had been fused by bone. Few epiphyses were observed to be in the process of uniting, and these epiphyses were considered open for these analyses. The range of union of each epiphysis was determined by observing the age of the youngest individual exhibiting epiphyseal union and the oldest individual exhibiting no epiphyseal union. The number of individuals within the range of union, the observed average age within the range of union (the average of the ages of the animals observed within the range of union), and the number of

TABLE III. Epiphyseal Fusion Time (Age in Years) in *S. fuscicollis*, *S. oedipus*, and *C. jacchus*

	Observed range ^a	No. in range	Observed average ^c	No. misclassified ^d
<i>S. fuscicollis</i>				
Scapula, coracoid process	0.72–0.73	2	0.73	2
Humerus, proximal	1.35–1.61	4	1.50	3
Humerus, distal	0.25 ^b –0.61	9	0.41	3
Humerus, medial epicondyle	0.72–0.81	3	0.75	2
Ulna, proximal	0.72–0.81	3	0.75	2
Ulna, distal	1.35–1.80	7	1.58	5
Radius, proximal	0.72–0.81	3	0.75	2
Radius, distal	1.35–1.80	7	1.58	5
Metacarpal	1.32–1.61	10	1.47	0
Sacrum, s1–s2	0.55–0.73	7	0.63	3
Innom, acetabulum	0.55–0.73	7	0.63	3
Innom, iliac crest	1.35–2.49	15	1.83	14
Innom, ischial tuberosity	1.35–2.03	13	1.72	8
Femur, head	0.81–1.32	2	1.06	0
Femur, greater trochanter	0.81–1.32	2	1.06	0
Femur, distal	1.47–1.85	8	1.66	6
Tibia, proximal	1.32–1.61	8	1.45	4
Tibia, distal	1.32			
Calcaneus	0.25 ^b –0.81	11	0.52	7
Metatarsal	1.32–1.33	2	1.32	0
Synchondroses				
Spheno-occipital	1.48–2.11	18	1.80	9
Spheno-ethmoid	1.48–2.09	17	1.78	12
<i>S. oedipus</i>				
Scapula, coracoid process	0.57–0.78	7	0.70	5
Humerus, proximal	1.24–2.07	18	1.64	8
Humerus, distal	0.30	0		0
Humerus, medial epicondyle	0.75–1.46	18	1.04	9
Ulna, proximal	0.75–1.46	18	1.04	9
Ulna, distal	1.67–2.10	12	1.89	8
Radius, proximal	0.75–1.55	20	1.09	10
Radius, distal	1.49–2.10	15	1.82	10
Metacarpal	0.75–1.75	25	1.21	9
Sacru, s1–s2	0.69–1.25	16	0.99	6
Innom, acetabulum	0.57–0.73	4	0.65	3
Innom, iliac crest ^c	2.35–3.49	6	2.95	4
Innom, ischial tuberosity	1.67–3.16	37	2.41	19
Femur, head	0.75–1.46	18	1.04	9
Femur, greater trochanter	0.75–1.46	18	1.04	9
Femur, distal	1.67–2.85	32	2.31	11
Tibia, proximal	0.75–2.85	53	1.83	10
Tibia, distal	1.04–2.07	21	1.57	5
Calcaneus	0.75–1.46	18	1.04	9
Metatarsal	0.75–1.75	25	1.21	8
Synchondroses				
Spheno-occipital	1.49–3.55	53	2.59	13
Spheno-ethmoid	1.49–3.53	53	2.59	13
<i>C. jacchus</i>				
Scapula, coracoid process	0.55–0.74	8	0.65	5
Humerus, proximal	1.08–2.24	20	1.47	7
Humerus, distal	0.50 ^b –0.58	3	0.55	2
Humerus, medial epicondyle	0.58–1.25	24	0.92	7
Ulna, proximal	0.88–1.25	13	1.08	9
Ulna, distal	1.08–2.24	20	1.47	5
Radius, proximal	0.88–1.25	13	1.08	9
Radius, distal	1.08–1.82	16	1.34	4

(continued)

TABLE III. (continued)

	Observed range ^a	No. in range	Observed average ^c	No. misclassified ^d
Metacarpal	1.08–1.25	9	1.14	7
Sacrum s1–s2	0.55–1.25	25	0.90	9
Innom, acetabulum	0.55–0.74	8	0.65	6
Innom, iliac crest ^e	1.46–7.93	80	4.45	27
Innom, ischial tuberosity	1.46–2.31	12	1.88	9
Femur, head	1.08–1.25	9	1.14	8
Femur, greater trochanter	0.93–1.25	12	1.10	9
Femur, distal	1.08–1.82	16	1.34	4
Tibia, proximal	0.93–1.82	19	1.28	5
Tibia, distal	0.88–1.25	13	1.08	5
Calcaneus	0.67–1.23	20	0.95	8
Metatarsal	1.08–1.25	9	1.14	8
Synchondroses				
Spheno-occipital	1.08–3.24	25	2.08	11
Spheno-ethmoid ^e	1.08–9.93	88	5.09	38

^aObserved range of union = youngest animal to exhibit epiphyseal fusion through oldest animal to exhibit open epiphysis.

^bYoungest animal in sample.

^cObserved average age of union = the average of the ages of the animals observed within the range of union.

^dMisclassified = sum of the number of animals younger than average with a closed epiphysis or older than average with an open epiphysis.

^eEpiphyseal centers which may not close in all animals.

misclassified individuals were calculated. Individuals were considered misclassified if their age was below the observed average age of union for a given epiphysis and they exhibited a closed epiphysis, or their age was above the observed average age of union and they exhibited an open epiphysis. This provides an indication of the observed variability in epiphyseal closure at each site in this sample.

Analysis of variance was used to test for sex differences in developmental age in each species. Developmental age, as indicated by the sum of the epiphyseal states of each individual, was not significantly different in males and females ($P > 0.05$) in *S. fuscicollis*, *S. oedipus*, or *C. jacchus*. Therefore, the males and females were combined in all subsequent analyses. This is consistent with the general lack of sexual dimorphism in tamarin and marmoset morphology [Leutenegger and Larson, 1985; Cheverud and Moore, 1990; Moore and Cheverud, 1992; Cheverud et al., 1993; Cheverud, 1995].

Multiple regression was used to estimate developmental age from the observed epiphyseal fusions, using only non-collinear epiphyses, that is epiphyses which did not close simultaneously. Only animals under 3 years of age and with complete data were used in this analysis. The state of the epiphyseal closure is the independent variable in the regression analysis. The chronological age is the dependent variable, as it is variable relative to developmental state. This regression can be used to represent the developmental state of the animal, or it can be used to estimate the chronological age of the individual [Cheverud, 1981]. This allows a comparison of animals on the same biological time scale, rather than in the chronological time. Twice the standard error of the estimate of the regression equation provides an estimate of the error in age estimation. This model is biased, however, since it fits the data used to estimate it, not just general data. Therefore, a jackknife procedure was used to estimate the standard error of the estimate [Sokal and Rohlf, 1969]. In this jackknife procedure, the regression equa-

tion was re-estimated a number of times (equal to the number of individuals in the sample), with one individual eliminated from each estimate. The generated regression equation was used to predict the age of the eliminated animal. The standard error of the regression is the standard deviation of the difference between the observed age and the predicted age of the eliminated individuals.

The sum of the epiphyseal states used in the regression analysis provides an additional estimate of developmental age. The developmental age can be used to test for species differences in development. A multivariate analysis-of-variance (MANOVA) was performed with developmental age (the sum of epiphyseal states), species, and the interaction of the developmental age and species as the independent variables and the chronological age as the dependent variable. A significant interaction between developmental state and species indicates that the species do not develop at the same rate.

We test the proposal by Washburn [1943] and Wintheiser and coworkers [1977] that the order of epiphyseal closure is similar across monkey species. We use pairwise Spearman rank correlations between the epiphyseal rankings of the species from this sample and published data on primate skeletal maturation. In addition to the tamarin and marmoset data included in these analyses, the intraspecific comparison includes data from *Saguinus nigricollis*, *Cebus albifrons*, *Saimiri sciureus* [Tappen and Severson, 1971], *Cercocebus albigena*, *Cercopithecus ascanius*, and *Cercopithecus aethiops* [Wintheiser et al., 1977], and *Macaca mulatta* [Cheverud, 1981].

RESULTS

The order of epiphyseal closure in each species is presented in Table III. In *S. fuscicollis* the earliest postcranial epiphyseal closure is seen at the distal humerus, with an observed average age of closure of 0.41 years. The last postcranial epiphysis to close in *S. fuscicollis* is the iliac crest, with an observed average age of closure of 1.83 years. The speno-occipital and speno-ethmoid synchondroses exhibit an observed average age of closure of 1.8 and 1.78 years, respectively. In *S. oedipus*, the earliest postcranial epiphysis to close is the acetabulum, with an observed average age of 0.65 years. Postcranial skeletal maturity is achieved in *S. oedipus* at an average of 2.95 years with the closure of the iliac crest. Closure of the speno-occipital and speno-ethmoid synchondroses occurs at an observed average age of 2.59 years. The distal humerus is the first site of epiphyseal closure in *C. jacchus*, with union at an observed average age of 0.55 years. Postcranial skeletal maturity is achieved by an observed average age of 1.88 years with the closure of the ischial tuberosity. Closure of the speno-occipital synchondrosis occurs at an observed average age of 2.08 years. A number of older individuals (over 3.5 years) exhibited an unfused iliac crest or speno-ethmoid synchondrosis, making these sites unreliable in age determination in *S. oedipus* and *C. jacchus*. These growth centers were not included in further analyses. The order of observed average ages of epiphyseal closure is similar across the three species ($r_s > 0.95, P < 0.05$).

It can be noted that while the order of epiphyseal closure is similar across species, the timing of closure of specific epiphyses is different across the species. Average closure age of 13 epiphyses is more than 0.25 years later in *S. oedipus* than in *S. fuscicollis*. *S. oedipus* grows for an average of 0.25 years longer than *C. jacchus* at 7 epiphyses, and *C. jacchus* grows for 0.25 years longer than *S. fuscicollis* at 7 epiphyses. These differing growth sites are distributed throughout the skeleton.

TABLE IV. Regression Coefficients for Calculation of Developmental State or Estimation of Chronological Age, R^2 , for Each Regression Equation, and the Standard Error of the Estimate (SEE) Calculated by a Jackknife Procedure

Variable	Coefficient		
	<i>Saguinus fuscicollis</i> (n = 22)	<i>Saguinus oedipus</i> (n = 43)	<i>Callithrix jacchus</i> (n = 30)
Constant	0.38	0.28	-0.03
Humerus, distal	0.12	0.20	0.65
Humerus, medial epicondyle	0.04	0.12	0.38
Humerus, proximal	0.27	-0.08	0.70
Radius, proximal		0.08	0.07
Radius, distal	0.10	0.18	
Innominate, acetabulum	0.18	0.44	0.23
Innominate, ischial tuberosity	0.35	0.92	
Femur, distal	0.02		
Femur, head	0.71	0.36	
Femur, greater trochanter		-0.07	
Tibia, proximal		0.92	
R^2	0.94	0.82	0.63
SEE	0.20	0.36	0.32

The epiphyses used to estimate chronological age and their regression coefficients are listed in Table IV. A subsample of individuals under 3 years was used in this analysis since complete data was needed for this analysis. Variables are not consistently used across species since only non-collinear epiphyses were used. Twice the standard error of the estimate after the jackknife procedure is 0.4 years (4.8 months) for *S. fuscicollis*, 0.72 (8.6 months) years for *S. oedipus*, and 0.64 years (7.6 months) for *C. jacchus*. Thus, we can use epiphyseal closure to predict the age of an animal to within 4.8 to 8.6 months of its actual age. As indicated by the R^2 values for the regression equations, the models explain from 63% (*C. jacchus*) to 94% (*S. fuscicollis*) of the variation in age prediction. These R^2 values differ across species due to differences in samples and included variables. In each species, there is no significant difference between an animal's known age and estimated age. The average difference between the observed and predicted ages is -0.026 years for *S. fuscicollis*, 0.012 years for *S. oedipus*, and -0.002 years for *C. jacchus*.

We test whether these tamarins and marmosets exhibit significantly different growth rates. The MANOVA results indicate that there is a significant age effect on growth ($P < 0.001$), and there is no significant effect of species ($P = 0.125$). There is a significant interaction between age and species ($P = 0.01$), indicating that the species have different growth rates. A MANOVA between pairs of species indicates that there is a significant difference between *S. fuscicollis* and *S. oedipus* in growth rates ($P = 0.004$), with *S. oedipus* growing more slowly. The difference between *S. oedipus* and *C. jacchus* approaches significance ($P = 0.08$) with *S. oedipus* growing more slowly than *C. jacchus*. There is no significant growth rate difference between *S. fuscicollis* and *C. jacchus* ($P = 0.52$).

The order of epiphyseal closure of the tamarins and marmosets from this study as well as other New World and Old World monkeys is significantly similar (Table V, $r_s > 0.76$, $P < 0.05$). This supports the suggestion of Washburn [1943] and Wintheiser et al. [1977] that there appears to be a general ordered trend in Primate skeletal growth. As illustrated in Figure 1, epiphyses in the elbow and hip close relatively early, and epiphyses in the shoulder, wrist, and knee close relatively late.

TABLE V. Pairwise Spearman Correlations Between Ranks Order of Epiphyseal Closure in 11 Primate Species^{a,*}

Species	1	2	3	4	5	6	7	8	9	10	11
1											
2	0.94										
3	0.85	0.90									
4	0.87	0.89	0.88								
5	0.79	0.76	0.89	0.85							
6	0.96	0.85	0.87	0.91	0.82						
7	0.80	0.82	0.80	0.94	0.89	0.82					
8	0.89	0.83	0.76	0.89	0.81	0.90	0.94				
9	0.91	0.90	0.98	0.90	0.88	0.92	0.78	0.79			
10	0.90	0.92	0.93	0.92	0.89	0.87	0.87	0.86	0.97		
11	0.88	0.91	0.97	0.92	0.90	0.87	0.84	0.81	0.99	0.99	

^aSpecies names and published sources. 1, *Saguinus fuscicollis* (this study); 2, *Saguinus oedipus* (this study); 3 *Saguinus nigricollis* [Tappen and Sevenson, 1971]; 4, *Callithrix jacchus* (this study); 5, *Cebus albifrons* [Tappen and Sevenson, 1971]; 6, *Saimiri sciureus* [Tappen and Sevenson, 1971]; 7, male *Macaca mulatta* [Cheverud, 1981]; 8, female *Macaca mulatta* [Cheverud, 1981]; 9, *Cercopithecus aethiops* [Wintheiser et al., 1977]; 10, *Cercopithecus ascanius* [Wintheiser et al., 1977]; 11, *Cercocebus albigena* [Wintheiser et al., 1977].

*All values significant at $P = 0.05$ level of significance.

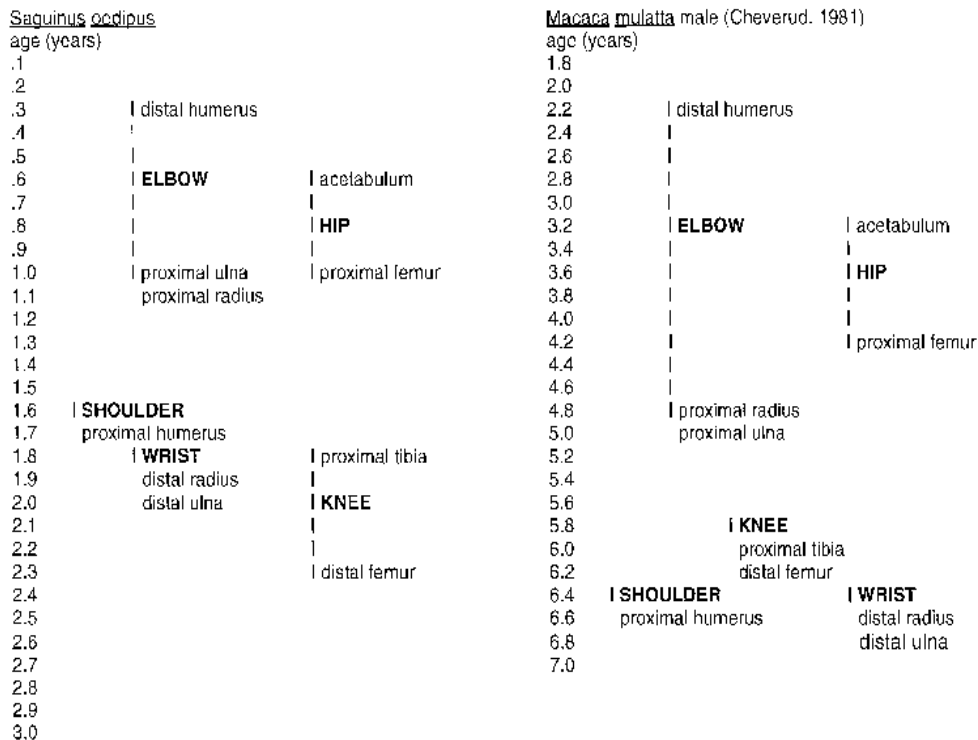


Fig. 1. Age of epiphyseal closure in New World and Old World monkeys as illustrated by *Saguinus oedipus* and male *Macaca mulatta* [Cheverud, 1981].

DISCUSSION

In these analyses we present a method of age prediction in tamarins and marmosets under 3 years of age based on epiphyseal closure. In an animal of unknown chronological age, age can be predicted to 0.40 to 0.72 years, depending on the species. Thus, age estimation may be sufficient to distinguish relatively mature and relatively immature individuals, but this process is not acceptable for studies where precise age estimates are necessary. These estimates based on developmental state are not as good as the average deviations of 0.40 years found by Gavan and Hutchinson [1973] who used number of teeth, body weight, and sitting height to estimate age. These data do not support their assertion that maturation criteria are better predictors of age than are size criteria; however, the results of this study are based on a much smaller sample size than that used by Gavan and Hutchinson. It should be noted that these results are based on cross-sectional skeletal data. A longitudinal sample of live individuals is likely to provide a better description of growth rates in these species.

The results from this study are similar to those found by Glassman [1983] on epiphyseal union in *S. fuscicollis* using part of this sample. Minor differences in estimated timing of epiphyseal closure probably arise from the differences in the sample makeup. Glassman's sample included more individuals under 1 year of age than were included in this study. However, a greater number of individuals over 1 year were represented in the current study.

There is considerable overlap in the timing of epiphyseal closure at different joints. For example, the elbow and hip joints mature simultaneously. This supports findings of Tappen and Severson [1971] and Glassman [1983] on tamarin epiphyseal closure. There is considerable variability in the length of time that it takes for joints to mature. For example, the elbow has a relatively long maturation period, while the knee and wrist have a relatively short maturation period.

The age of epiphyseal closure for growth centers is different across species. *S. oedipus* has the longest growth period at 75% of the epiphyses and *S. fuscicollis* has the shortest growth period at 60% of the epiphyses, and an intermediate growth period in *C. jacchus*. This differences in growth period results in skeletal dimensions which are largest in *S. oedipus*, and *C. jacchus* is significantly smaller than *S. fuscicollis* in many skeletal dimensions (unpublished data). These skeletal dimensions mirror body size of tamarins and marmosets, with average weights for *C. jacchus*, *S. fuscicollis*, and *S. oedipus* reported at 200–325, 310–410, and 400–450 g, respectively [Garber, 1992].

These relationships in skeletal development reflect the evolutionary history of these taxa. It is generally agreed that there has been a decrease in body size during the evolution of the Callithrichinae to the extant species, with a greater decrease in evolution of *Callithrix* than in *Saguinus*. These body size differences correspond to general ecological differences in specializations in diet, locomotion, and resource use [Ford and Davis, 1992], and include numerous morphological and behavioral differences [Garber, 1992]. Selection for these specializations has, at least in part, been achieved by differences in the length of the growth period.

The relative order of monkey epiphyseal closure is similar across monkey species, supporting the findings of Washburn [1943] and Wintheiser et al. [1977]. As indicated in Figure 1, the elbow and hip mature relatively early, while the shoulder, wrist, and knee mature relatively later in the developmental process. These results suggest that there may be an overall evolutionary pattern of Primate epiphyseal closure, and the pattern does not appear to be species specific. This may be useful in further studies using Primates of unknown age.

CONCLUSIONS

1. The observed order of epiphyseal closure is similar in tamarins and marmosets.
2. There is a difference in the relative growth rate between the species, with *S. fuscicollis* reaching skeletal maturity relatively early, and *S. oedipus* growing for a significantly longer period of time.
3. Based on this sample, epiphyseal closure can be used to predict age to within 4.8 months for *S. fuscicollis*, 8.6 months for *S. oedipus*, and 7.6 months for *C. jacchus*. Such estimates are useful to determine if an animal of unknown age is relatively young or relatively old, but are not useful for studies that require more precise age estimates.
4. There appears to be a general ordered trend of epiphyseal closure in Primate skeletal growth. In general, epiphyses in the elbow and hip close relatively early, and epiphyses in the shoulder, wrist, and knee close relatively late.

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