The Endocrinology of Puberty and Reproductive Functioning in Female Cotton-Top Tamarins (Saguinus oedipus) under Varying Social Conditions

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ABSTRACT

Sexual maturation and fertility were assessed in fourteen cotton-top tamarin (Saguinus oedipus) females under various social conditions. Six tamarin females (20–28 mo of age) showed a suppression of fertility while living with their families. Hormonal profiles demonstrated low, acyclic levels of urinary luteinizing hormone (LH) and estrone-conjugates (E1C). A rapid onset of ovarian and pituitary cyclicality occurred when four of the six females were removed from their families and paired with an unrelated male. In one female, an ovulatory LH peak occurred as early as eight days after pairing and resulted in conception and full-term pregnancy. Two of the six females were housed in total isolation for 30 days following their removal from the family and prior to pairing. Gradual increases in hormone concentrations occurred during isolation; however, there was no ovarian cyclicity until each female was paired with an unrelated male. In all six females, conception occurred before or as a result of the third ovulatory cycle. Partial isolation of a 36-mo-old female resulted in elevated LH and E1C levels, but cyclicality was not observed until the female was paired with an unrelated male. These findings indicate that removal of a female from the family alone does not initiate ovarian cycling. Sexual maturation, or puberty, occurs in female tamarins living with their families between 15 and 17 mo of age when mean LH and E1C levels began to increase. However, when a female is removed and paired at 9 mo of age with an unrelated male, elevated levels of LH and E1C may be seen by 10 and 11 mo of age. Our findings indicate that a suppression of fertility occurs in cotton-top tamarins living with their families, but that reproductive suppression does not affect the process of sexual maturation. Both removal from the family environment and stimulation by an unrelated male tamarin were necessary to induce normal reproductive activity. An acceleration of puberty occurred when a female tamarin was removed from her family early in development and paired with a male.

INTRODUCTION

The social environment of female primates can have a pronounced effect on their fertility. Lowered fertility in subordinates has been reported in several primate species, including marmosets (Abbott et al., 1981; Abbott, 1984; Evans and Hodges, 1984), tamarins (Eppele and Katz, 1984; French et al., 1984; Tardif, 1984), talapoins (Bowman et al., 1978; Keverne, 1979; Keverne et al., 1984; Abbott et al., 1986), macaques (Drickamer, 1974), and baboons (Rowell, 1970; Dunbar, 1980). Subordinate or low-ranking females may have reduced fertility in response to behavioral and endocrine changes. Lowered fertility may be manifested in lower incidences of infant survival, sustained pregnancy, conception, or even of ovulation and normal ovarian cyclicity.

In Callitrichid species (marmosets and tamarins), the social group consists of a stable nucleus comprising a breeding female, an unrelated male with which a monogamous pair bond may be formed, successive sets of offspring, and possibly other unrelated male and females (Dawson, 1977; Neyman, 1977; Izawa, 1978; Eppele and Katz, 1984; Terbohr, 1984). Within this social system, all other females are subordinate to the breeding female. In captivity, this subordination has been associated with suppression of fertility in female offspring who remain caged with their natal family. In the common marmoset (Callitrichus jacchus),
Evans and Hodges (1984) reported no cyclic pattern in urinary pregnanediol-glucuronide while female offspring remained in the family up to 25 mo of age, but a rapid onset of cyclicity occurred when the females were paired with males. Abbott (1984) has shown that in approximately 50% of marmoset families, one adult female offspring over 12 mo of age will ovulate while living with the family. However, no pregnancies resulted under these conditions. Saddleback tamarins (Saguinus fuscicollis) have not exhibited cyclicity in urinary estrogens when they remain with their families until 25 mo of age (Epple and Katz, 1984). Also, cotton-top tamarins (S. oedipus) have been reported to have low, acyclic levels of urinary estrogens when they remain with their natal families for up to 40 mo of age (French et al., 1984).

It is unclear what effect the suppression of fertility has on the sexual maturation, or puberty, of young daughter Callitrichids. Tardif (1984) found that daughters who were removed from the family and paired with an unrelated male matured at an earlier age (15 mo) than daughters who remained with their families (21 mo). Maturity in Tardif's study was assessed by increased levels of plasma progesterone and progesterone peaks indicative of ovulation. When removed from the family, common marmosets have ovulated by 13 mo of age (Abbott and Hearn, 1978), and saddle-back tamarins have conceived as early as seven mo of age when paired with an older adult male (Epple and Katz, 1980). Whether this is an acceleration of puberty or a release of family-induced fertility suppression is unclear.

Urinary estrogen peaks have been shown to occur in the luteal phase of the cycle in the cotton-top tamarin, and therefore, urinary estrogen peaks are not indicative of ovulation (Ziegler et al., 1987). To date, progesterone and pregnanediol have been undetectable in cotton-top tamarins' urine (Brand, 1981; Ziegler, unpublished data). Measuring urinary luteinizing hormone (LH) activity, therefore, is important to the assessment of ovulatory activity in cotton-top tamarins, especially during the suppression of estrogen cyclicity that occurs when female offspring remain in their natal family. Since Tardif (1984) and French et al. (1984) have found measurable levels of serum progesterone and urinary estrogens, respectively, in female offspring that remain in the natal family, it is important to determine the gonadotropic excretion indicative of ovulation as well. LH is also an important indicator of sexual maturation of the hypothalamus and pituitary (Terasawa et al., 1983).

The present study was undertaken to further our knowledge of fertility suppression and its relationship to sexual maturation in Callitrichids. Female cotton-top tamarins were studied at various ages and in several social environments by monitoring urinary levels of LH and estrone 1) to determine the LH response to family induced fertility suppression, 2) to assess fertility when female offspring are removed from their families, and 3) and to determine what effect the social environment has on sexual maturation.

**MATERIALS AND METHODS**

**Subjects**

The subjects, 14 cotton-top tamarin females, were second and third generation captive-born. All of the females were raised in large, stable families containing a breeding male and female with their offspring, except Ann, who was hand-reared. Table 1 lists the age in months of females studied while in their families, upon pairing with an unrelated male, and their social conditions. The housing conditions were as follows: large family cages (1.8 mW × 3.0 mL × 2.3 mH), male-female pair cages (0.85 mL × 1.5 mL × 2.3 mH), and isolation cages (0.64 mL × 0.64 mL × 2.44 mH). All cages contained an elaborate system of branches, ropes, and a nest box. (For further details of caging, husbandry, and diet, see Snowdon et al., 1985).

**Sampling Techniques**

Early morning urine (EMU) was collected as the first void of the morning and was obtained from each female without restraint, isolation or handling. Details of the collection and storage technique have been described (Ziegler et al., 1987) with the following modifications. Urine was collected in polypropylene containers (rodent cages, American Scientific Products, McGraw Park, IL) to prevent steroids from adhering to the container. Prior to freezing, samples were centrifuged (1000 × g for 5 min) and divided into two aliquots for steroid and protein determination. To the aliquots for gonadotropin determination, 0.52 mol/l glycerol (Sigma Chemical Co., St. Louis, MO) was added to stabilize the peptide molecules while frozen (Livesey et al., 1983). Urine was collected daily or a minimum of three times per week for all social conditions. Urine collection was attempted daily for newly paired subjects, but increased scent marking often prevented collection.
TABLE 1. Age in mo of female offspring at each social condition.

<table>
<thead>
<tr>
<th>Subject</th>
<th>Family</th>
<th>Isolation</th>
<th>Paired</th>
<th>Sibling</th>
<th># in Family</th>
<th>Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lew</td>
<td>20–27</td>
<td>—</td>
<td>27</td>
<td>twin(Kia)</td>
<td>8</td>
<td>I</td>
</tr>
<tr>
<td>Kla</td>
<td>20–27</td>
<td>—</td>
<td>27</td>
<td>twin(Lew)</td>
<td>8</td>
<td>I</td>
</tr>
<tr>
<td>Pip</td>
<td>23–26</td>
<td>—</td>
<td>26</td>
<td>twin(male)</td>
<td>6</td>
<td>I</td>
</tr>
<tr>
<td>Hal</td>
<td>20–26</td>
<td>—</td>
<td>27</td>
<td>twin(male)</td>
<td>8</td>
<td>I</td>
</tr>
<tr>
<td>Yas</td>
<td>25–28</td>
<td>28–29</td>
<td>29</td>
<td>twin(Zie)</td>
<td>8</td>
<td>I&amp;IIc</td>
</tr>
<tr>
<td>Ze</td>
<td>25–28</td>
<td>28–29</td>
<td>29</td>
<td>twin(Yas)</td>
<td>8</td>
<td>I&amp;II</td>
</tr>
<tr>
<td>Hdy</td>
<td>—</td>
<td>36–39</td>
<td>39</td>
<td>—</td>
<td>—</td>
<td>III</td>
</tr>
<tr>
<td>Ann</td>
<td>—</td>
<td>10</td>
<td>10</td>
<td>handreared</td>
<td>—</td>
<td>IIId</td>
</tr>
<tr>
<td>Lau</td>
<td>12–17</td>
<td>—</td>
<td>—</td>
<td>twin(male)</td>
<td>6</td>
<td>III</td>
</tr>
<tr>
<td>Kim</td>
<td>13–16</td>
<td>—</td>
<td>—</td>
<td>twin(male)</td>
<td>5</td>
<td>III</td>
</tr>
<tr>
<td>Ren</td>
<td>11–19</td>
<td>—</td>
<td>—</td>
<td>twin(male)</td>
<td>5</td>
<td>III</td>
</tr>
<tr>
<td>Cas</td>
<td>13–19</td>
<td>—</td>
<td>—</td>
<td>twin(male)</td>
<td>7</td>
<td>III</td>
</tr>
<tr>
<td>Ant</td>
<td>15–19</td>
<td>—</td>
<td>—</td>
<td>trip(male, D6)</td>
<td>4</td>
<td>III</td>
</tr>
<tr>
<td>Sca</td>
<td>11–19</td>
<td>—</td>
<td>—</td>
<td>twin(male)</td>
<td>5</td>
<td>III</td>
</tr>
</tbody>
</table>

\(^{a}\)D Indicates death of infant.

\(^{b}\)Condition I females were housed with their families and then paired with an unrelated male.

\(^{c}\)Condition II females were isolated and housed in individual cages before pairing with an unrelated male.

\(^{d}\)Condition III females were prepubertal at the beginning of sampling and lived with their families or with an unrelated male.

Assays

A method for measuring estrone-conjugates (E1, C) by radioimmunoassay (RIA) directly in the urine was developed and validated. Estrone is known to be the predominant urinary estrogen in cotton-top tamarins (Hodges and Eastman, 1984) and reflects the endocrine events of parturition, estrogen cyclicity, and pregnancy (Ziegler et al., 1987). Estrone-3-glucuronide (E1 G) rabbit antiserum (developed and donated by Dr. J. K. Hodges) measured estrone in its conjugated form and showed the following cross-reactivities: 105% estrone, 49.6% estrone-3-sulfate, 3.05% estriol, 1.08% estradiol-3-glucuronide, 0.92% estradiol-17β, 0.73% estriol-3-glucuronide, 0.68% estradiol, and less than 0.005% with all other steroids tested. E1 G, obtained from Sigma Chemical Co., was used for standards, and \(^{3}\)H-E1 G, obtained from Amersham (Arlington Heights, IL), was used as tracer. Serial dilutions of cotton-top tamarin urine gave a displacement curve parallel to that obtained with E1 G standards. The sensitivity of the assay was 4 pg/tube and the intra- and interassay coefficients of variation were 6.25% and 4.49% (\(n=34\) respectively. This method of measuring E1 correlated well with our previous method (Ziegler et al., 1987) of enzyme hydrolyses, extraction, column separation, and individual RIA of E1 during the ovulatory cycle of three female cotton-top tamarins (\(r=0.98, n=29; r=0.96, n=19; r=0.88, n=27\)) and during pregnancy in one tamarin (\(r=0.91, n=88\)).

To determine ovulation and pregnancy (since estrogen peaks are not indicative of ovulation), immunoreactive luteinizing hormone/chorionic gonadotropin (LH/CG) was measured using the method of Toivola et al. (1978) as a mixed heterologous RIA. This procedure correlated closely with bioactive measurement of LH/CG (\(r>0.80\) in over 300 samples) and has been described elsewhere (Ziegler et al., 1987). The intrassay coefficients of variation were 11.87% (\(n=28\)) and 17.6% (\(n=4\)) and the interassay coefficient of variation was 13.53% (\(n=6\)).

Urinary hormone concentrations were corrected for variable urine output by measuring creatinine (Cr) concentration (Tietz, 1976) and dividing Cr into hormone concentration. Hormone values were expressed per mg of Cr.

Determinaton of Cycles and Pregnancies

Hormonal profiles are shown in Figure 1 for urinary LH and E1 C in a cycling female. The typical pattern seen in cotton-top tamarins of elevated estrogens occurring after the LH peak is indicated. Hormonal profiles during ovarian cycles and pregnancies have been described by the method found in Ziegler et al. (1987). By monitoring adult breeding females for urinary estrogen and LH/CG excretion, we found prominent LH/CG peaks with corresponding increases in E1 and E2 on the day of the LH/CG peak. Urinary estrogens continued to increase and
remained at high levels for approximately 15 days, and then decreased if conception had not occurred. If conception occurred, then an increase in LH/CG occurred approximately 20 days after the peri-ovulatory LH/CG peak. The estrogens began to increase again shortly after this. LH/CG remained high for approximately 80 days, and the estrogens reached their maximum levels at midpregnancy and dropped sharply at parturition. The gestation length is approximately 183 days.

Experimental Conditions

**Condition I.** Six of the subjects were studied first in their natal family cage. All subjects were the oldest female offspring and were housed in large families. The adult breeding female of each family was pregnant throughout the entire sampling period, except for one female who gave birth to twins during the sampling period. Two sets of twin females and two females with twin males were studied. All six were older than 24 mo; this is the age at which tamarins are normally removed from their natal family and paired in our colony to maximize reproduction. Control data were not obtained on female offspring living with their natal family past 28 mo of age. However, family-induced fertility suppression was not age-dependent; our colony has had four females who had failed to show signs of ovarian activity prior to pairing with a male. Three female offspring had remained with their natal family up to 36 mo of age with no overt signs of fertility. One of these females was monitored for urinary estrogens and showed no estrogen cyclicity. Another female remained housed with her female twin until she was 42 mo of age and showed no cyclicity in urinary estrogens (French et al., 1984). Four of the six subjects studied in their natal family were then removed and paired with an unrelated male in another colony room. Hormones were monitored for four to five months following pairing.

**Condition II.** Females were isolated from conspecifics to determine if reproductive cycling could be initiated by removal from the natal family, or if the stimulus of an unrelated male was needed. Two of the above-mentioned females were isolated for one mo after removal from the family, but prior to pairing with an unrelated male. These two subjects were in total isolation, with no auditory, olfactory, or visual contact with each other or any other tamarin. Another female was studied under partial isolation. This female had been removed from her family but remained unpaired for 18 mo. During the study, this female was housed alone in a room with other cages that allowed auditory and olfactory, but no visual, contact with other male and female tamarins. Urine was collected for two mo during partial isolation and then for two mo after pairing with an unrelated male.

**Condition III.** Since the first six females had low, acyclic, but measurable, levels of hormones while living with their families (age 20–28 mo), six additional females (see Table 1) were monitored at an earlier age while still housed in their families to determine when hormonal levels began to increase. These females were monitored from 11 to 19 mo of age. A mean monthly concentration of hormone was determined for each female, and the total mean ± SE was determined for all six females for each month. An additional female was paired with an unrelated male at 9 mo of age and studied for two mo to determine if early pairing accelerated sexual maturation, in contrast to young females who remained with their families. The mean ± SE hormone level for each month was determined.

**RESULTS**

**Condition I.** All six females showed essentially the same pattern of low, acyclic concentrations of E1, C, and LH while living with their families (see Figures 2 and 3). For the six subjects, the mean level was 1.22 μg/mgCr ± 0.36 SE for E1, C and 258.81 ng/mgCr ± 61.84 SE for LH. There was no ovarian cycling of
E, C. All female offspring living in families had fluctuating levels of LH, with peaks occurring at ovulatory levels of cycling females. None of the LH peaks were associated with corresponding increases in E, C concentration, as shown in Figure 1 in a normally cycling female, and they occurred too frequently to indicate ovulation. In female Lew, basal levels of LH were elevated during the 26th month, but E, C remained low. This same profile was seen in Hal at 20 mo of age for approximately 50 days until levels declined.

Upon pairing with an unrelated male, E, C and LH increased dramatically for all females. The mean concentration of E, C after pairing was 11.62 μg/mgCr ± 2.02 SE and for LH was 1171.60 ng/mgCr ± 496.64 SE for the six subjects. Hormonal concentrations
TABLE 2. Reproductive data in days from six cotton-top tamarin females following pairing with an unrelated male.*

<table>
<thead>
<tr>
<th>Subject</th>
<th>Days to first LH peak</th>
<th>Days from first LH peak to second</th>
<th>Days from second LH peak to third</th>
<th>Conceptiona</th>
<th>Gestation length &amp; # of infants born</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lew</td>
<td>8</td>
<td>-</td>
<td>-</td>
<td>8</td>
<td>186, single</td>
</tr>
<tr>
<td>Kla</td>
<td>37</td>
<td>26</td>
<td>-</td>
<td>64</td>
<td>187, single</td>
</tr>
<tr>
<td>Pip</td>
<td>45</td>
<td>32</td>
<td>27</td>
<td>105</td>
<td>72, abortionb</td>
</tr>
<tr>
<td>Hal</td>
<td>33</td>
<td>21</td>
<td>25</td>
<td>80</td>
<td>182, single</td>
</tr>
<tr>
<td>Yas</td>
<td>18</td>
<td>-</td>
<td>-</td>
<td>18</td>
<td>184, twins</td>
</tr>
<tr>
<td>Zie</td>
<td>70</td>
<td>24</td>
<td>-</td>
<td>94</td>
<td>184, twins</td>
</tr>
</tbody>
</table>

*aConception is defined by the number of days to the fertile LH peak.

bAbortion occurred when female was transferred to another colony.

*Day 1 is defined as the day the females were paired with a male. LH = luteinizing hormone.
were statistically greater after the females were paired than before (one-tailed, \( t=4.95, p<0.005 \) for \( E_1 \) C and \( t=1.87, p<0.10 \) for LH). These increases were associated with an immediate rise in basal levels of \( E_1 \) C and LH, hormonal cycling, conceptions and pregnancies. Table 2 lists the number of ovulatory LH peaks, the day of conception, and the gestational length for the six subjects. The first ovulatory LH peak occurred as early as eight days after pairing in Lew and as late as 70 days in Zie. Lew and Yas conceived after the first LH peak, Kla and Zie conceived after the second LH peak, and Pip and Hal conceived after the third. All females had normal pregnancies with live-term infants, although there was a higher incidence of single births than the normal 18% for established breeding females in our colony (see Snowdon et al., 1985). Figure 2 illustrates the rapid increase in hormonal activity for twin females when paired with unrelated males. The hormonal patterns of ovulation and pregnancies were essentially identical to those in our established breeding females (see Ziegler et al., 1987). In two females, Kla and Zie, a urine sample was missed on the day of the fertile LH peak. However, the profile of increased estrone and increased CG 20 days later identified the timing of the fertile LH peak. Of the females that had more than one cycle prior to conception, the cycles appeared normal, and cycle lengths were within the normal range for adult breeding cotton-top tamarins (19–31 days, French et al., 1983).

**Condition II.** Figure 3 shows the effects of complete isolation of 30 days on two subjects. For Yas, both \( E_1 \) C and LH concentrations began to increase and continued rising throughout the isolation phase. In contrast to control levels (Fig. 1) where LH remained low except for a single day, basal levels of LH were highly elevated and there were no LH peaks associated with corresponding increases of \( E_1 \) C to indicate ovarian cyclicity. Hormone concentrations remained low in Zie throughout the isolation phase until ten days prior to pairing, when both \( E_1 \) C and LH levels began to increase steadily. There was no indication of ovarian cycling in this subject during isolation.

Figure 4 shows the hormonal profile for female Hdy during partial isolation and after pairing with an unrelated male. No ovarian cyclicity occurred during isolation, but both hormones were within the normal range for adult breeding females (see Ziegler et al., 1987). Basal LH and \( E_1 \) C concentrations were elevated and numerous peaks occurred. Once Hdy was paired, basal levels of both hormones dropped, and an ovulatory LH peak occurred with corresponding increases in \( E_1 \) C within 23 days. Conception and a 183-day pregnancy followed, culminating with the birth of viable twin infants. This subject ovulated only once prior to pregnancy.

**Condition III.** Table 3 gives the mean ± SE monthly \( E_1 \) C and LH levels for six cotton-top tamarin juveniles living with their families during ages 11–19 mo, and the mean monthly \( E_1 \) C and LH levels for Ann, who was living with an unrelated male when she was 10 and 11 mo of age. \( E_1 \) C and LH increased between 15 and 17 mo of age in all of the juveniles living with their families. The mean LH concentration was

![Hormonal profiles of urinary luteinizing hormone (LH) and estrone-conjugate (E1C) for an individual female during partial isolation and after pairing with a male tamarin. The LH peak was missed due to a missed urine sample on Day 11 of the 39th mo. Ov = ovulatory LH peak, CG = rise of chorionic gonadotropin after implantation.](image-url)
elevated by the sixteenth month and a threefold increase occurred in the mean E1C concentration between the 17th and 18th month. Both hormones continued to increase through 20 mo of age. However, no ovarian cyclicity occurred and these elevated levels were still well below levels found in reproductively active adult females (mean adult E1C levels were 11.52 ± 2.03 μg/mgCr, and mean adult LH levels were 1146.41 ± 504.75 ng/mgCr). In contrast, Ann, who was paired with an unrelated male, had elevated E1C and LH levels at 10 and 11 mo of age.

DISCUSSION

The results indicate that females who remain with their natal families for up to 28 mo do not show cyclic patterns of LH and estrogen. This lack of cyclicity in the family condition is probably not age-dependent, since females who remained with their families up to 36 and 42 mo did not display ovarian cyclicity as well (unpublished data; French et al., 1984). Although cycling did not occur under this social condition, hormonal maturation was not affected since detectable levels of both LH and estrone were secreted. While female offspring remained in their families, the normal feedback response between LH and estrogen was not found. In fact, basal LH levels, independent of estrone feedback, increased to very high levels in several females; however, this increase was not age-dependent since it occurred in Hal at 20 mo of age, and in Yas and Lew at 26 mo of age. These levels subsequently declined in Hal and Yas, but Lew was removed for pairing before a decline could be seen.

Rapid onset of ovarian cycling with conception after pairing has not been demonstrated before. This indicates that the females are reproductively mature before 28 mo of age and are fertile as soon as the proper social environment is present. French et al. (1984) demonstrated a rapid onset of urinary estrogen cycling after pairing in the cotton-top tamarin, but none of the females conceived during that study. This might have been due to the effects of stress caused by capturing the females for urine collection. However, our method allowed us to collect urine without restraint or disturbance to the newly paired tamarins. Epple and Katz (1984) also reported an immediate occurrence of urinary estrogen cyclicity in saddleback tamarins when removed from the family (estrogen peaks as early as 12 days). Since these females were paired with vasectomized males, no information on early conceptions was possible. In the common marmoset, Evans and Hodges (1984) demonstrated cyclicity of urinary pregnanediol occurring within 18–22 days after removal from the family, but these females were not paired with males.

Puberty is a complex process that occurs over an extended period of time in primates (Ojeda et al., 1980). In New World monkeys, only Callithricidae and Saimiri have been studied in detail. Callithricids and squirrel monkeys show puberty only under appropriate environmental conditions. For squirrel monkeys, the environment is appropriate with the achievement of critical body weight and only during a discrete mating season (Coe et al., 1981). In callithricids, the environment is appropriate when a female is removed from the natal family and exposed to a novel male. The process of sexual maturation in callithricids is masked by the suppression of fertility that occurs while a female lives with the natal family. Not only are cotton-top tamarins and squirrel monkeys ovulating almost immediately with proper environmental conditions, but conceptions and full-term pregnancies occur. It is highly unlikely that the entire process of puberty could occur as rapidly as eight days (Fig. 2) in a New World monkey. In fact, the rise of LH and estrone concentration by the 17th month seemed to indicate that the onset of sexual maturation may be completed as early as 18 mo of age. In addition, Tardif (1984) noted the occurrence of circulating levels of progesterone by 22 mo of age in female cotton-top tamarins living with their families.

A novel male had a considerable effect on a female's hormonal cyclicity. Immediate cyclicity did not occur in females isolated after separation from their family, in contrast to the other females who showed an onset of cyclicity and fertility. This suggests that removal from the family alone does not induce ovulation. In our study, isolation was complete, with no auditory, olfactory, or visual contact with any other male or female tamarin. For the female Hdy, who was in partial isolation, pairing with a male resulted in cessation of erratic estrone and LH fluctuations. The only other study that has monitored female callithricids in isolation showed that three common marmoset daughters removed from their families began urinary pregnanediol cyclicity as early as 18 days after removal (Evans and Hodges, 1984). The conditions of isolation for the common marmoset were not clearly described. Therefore, the cotton-top tamarin may be different from the common marmoset in that ovulation does not occur without the presence of a novel male.
Male tamarins also may have an accelerating effect on a female's sexual maturation. Ann, who was paired much earlier than normal (9 mo) began to show elevated hormone levels at 10 mo of age. Unfortunately, only one female was available to demonstrate acceleration of puberty, since early removal from the family before adequate infant caretaking experience has a profound effect on a female's ability to rear her own offspring (Snowdon et al., 1985). In mice and voles, the ability of males to cause an acceleration of puberty has been well documented (Vandenbergh, 1967; Vandenbergh, 1969; Kennedy and Brown, 1970; Drickamer, 1982; Lepri et al., 1985). The odor of a male mouse is the critical agent in causing the acceleration of puberty in female mice (Vandenbergh, 1969); but more specifically, chemosignals in the urine of male mice generate neuroendocrine responses that influence puberty by transmission via the vomeronasal system (Lepri et al., 1985).

In primates, such as callitrichids, which show both an acceleration of puberty in response to a male stimulus and a suppression of fertility when in a subordinate position to the breeding female, chemical signals may be excreted either in the urine or by scent glands. In the saddle-back tamarin, transfer of scent secretions from the family prevented normal estrogen cycles in one female after she was paired with a male (Epple and Katz, 1984). A similar study from our laboratory with the same subjects used in the present study revealed that female offspring who received their family's scent after they were paired with an unrelated male had significantly delayed ovulations. Furthermore, no conceptions occurred while the scent was being transferred (unpublished data). It is therefore quite likely that the reproductive status of Callitrichids is influenced by chemosignals.

Whether the effects of reduced fertility are more pronounced in captivity than in the wild is uncertain. Field studies of the *Saguinus oedipus* species have reported only one female producing offspring in a group (Dawson, 1977; Neyman, 1977). It is possible that the family-induced fertility suppression seen in captivity may be enhanced due to an increase in population density and the inability of female offspring to emigrate from the family. Also, closer proximity to the breeding female may allow for the suppressive effects to last longer after the female offspring has reached the age of puberty. To date, there are no available data on hormonal status in tamarin groups in the wild. With our improved techniques for collecting urine and the development of fecal assays, it may soon be possible to obtain hormonal data on tamarins in large outdoor enclosures or in the wild.

ACKNOWLEDGMENTS

Donation of the estrone-glucuronide antiserum by Dr. J. K. Hodges is greatly appreciated. The authors would like to thank D. Whittwer, F. Wegner, and K. Ombremski for technical assistance and C. Sweet, M. Carr, S. Rubin, J. Wilker, M. Larson, M. Bradford, and M. Ott for sample collection. We thank F. Bercovitch, L. Dronzek, B. L. Lasley, and L. C. Drickamer for manuscript criticism, and R. W. Goy and W. E. Bridson for the use of the assay laboratories, and S. D. Tardif for donation of some urine samples.

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