

Hair Loss and Hair-Pulling in Rhesus Macaques (*Macaca mulatta*)

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Alopecia is a common problem in rhesus macaque colonies. A possible cause of this condition is hair-pulling; however the true relationship between hair-pulling and alopecia is unknown. The purpose of this study was to examine the relationship between hair loss and hair-pulling in 1258 rhesus macaques housed in 4 primate colonies across the United States. Alopecia levels ranged from 34.3% to 86.5% (mean, 49.3%) at the primate facilities. At facilities reporting a sex-associated difference, more female macaques were reported to exhibit alopecia than were males. In contrast, more males were reported to hair-pull. Animals reported to hair-pull were significantly more likely to have some amount of alopecia, but rates of hair-pulling were substantially lower than rates of alopecia, ranging from 0.6% to 20.5% (mean, 7.7%) of the populations. These results further demonstrate that hair-pulling plays only a small role in alopecia in rhesus macaques.

Alopecia (hair loss) is a substantial problem in rhesus macaque colonies, with an estimated prevalence of around 48% of animals exhibiting it at some point in their history¹² and with numbers reaching as high as 68% in some populations.²⁰ Hair loss can range from small focal areas to whole body parts (for example, the back) to the entire body missing hair.^{9,11,19} Although alopecia is not an uncommon condition, its etiology is not fully understood, with many contributing factors including seasonal variation, aging, rank, sex, housing condition, reproductive state, skin disorders, and nutritional deficiencies, behavioral pathology, and stress.^{5,12,17,20,22} Little is known about the relative contribution of various factors to alopecia in colony primates, but the assumption has often been that alopecia is primarily the result of a particular behavioral pathology (that is, hair-pulling) or the stress of the captive environment. Whatever the cause, alopecia is often considered to be a sign of poor welfare and subjected to increased regulatory attention.^{1,13}

Hair-pulling is a syndrome that includes plucking hair from the body by using hands or teeth, manipulating it, and frequently ingesting it.^{3,14,17,18} Methods of hair removal range from pulling out fistfuls of hair to plucking out single hairs at a time to overgrooming (self-grooming in excess), and the resulting coat can have bald or patchy patterns.⁸ In cases where excessive hair is ingested by monkeys, gastric trichobezoars (that is, hair balls) can result, potentially leading to serious clinical complications.¹⁶ The prevalence of hair-pulling in individually housed monkeys is about 14% and is associated with increased age,¹⁴ but a more recent study reported overall rates as high as 33%.¹³ This pattern of hair-pulling is similar to that observed in the human disorder trichotillomania which also involves plucking out, and sometimes ingesting, hair.^{6,23} People have reported that hair-pulling is sometimes associated with increasing tension or stress, which can be alleviated with the act of pulling out hair.^{6,21}

However, in rhesus macaques, stress does not appear to be a factor in hair loss.^{12,13}

The true relationship between hair-pulling and alopecia is currently unknown. Although it is likely that hair-pulling produces hair loss in some rhesus macaques, it is unlikely that all cases of hair loss are attributable to the hair-pulling syndrome. In one study, a significantly higher proportion of rhesus monkeys with alopecia were observed to hair pull (53.9%), but 12.8% of the control population (with less than 10% hair loss) were observed to hair-pull, and for animals with alopecia, the location of the hair-pulling was not always near the site of alopecia.¹³ In addition, one singly housed rhesus monkey developed gastric trichobezoars from hair eating but was reported to have a good coat of hair.¹⁶ Further complicating this relationship between hair-pulling and alopecia is social housing. Monkeys can pull their own hair or that of others (or both). In a study of 2 breeding groups of rhesus macaques, monkeys pulled hair at the rate of 2.4 episodes per hour, and most of the episodes were directed toward other monkeys rather than to self (97% compared with 3%, respectively).¹⁸ In addition, limited enclosure space appears to have an additional effect on hair loss in group-housed rhesus monkeys.^{5,19}

The purpose of the current study was to examine the relationship between alopecia and hair-pulling behavior in individually housed rhesus macaques in 4 primate colonies across the United States. There were 3 objectives. The first objective was to characterize the prevalence of alopecia and hair-pulling by using a simple 'yes–no' scoring system, with any hair loss or observation of hair-pulling scored as 'yes.' In the second objective, we examined prevalence as a function of facility. Animal management practices vary quite widely across primate facilities² and may differentially affect the extent of both alopecia and hair-pulling. Therefore, we assessed commonalities and differences in alopecia and hair-pulling across primate centers. The final objective was to determine whether hair-pulling was a primary factor of hair loss in individually housed monkeys.

Materials and Methods

Subjects. The subjects were 1258 rhesus macaques (*Macaca mulatta*; 554 females and 704 males; age, 1 to 26 y). The animals

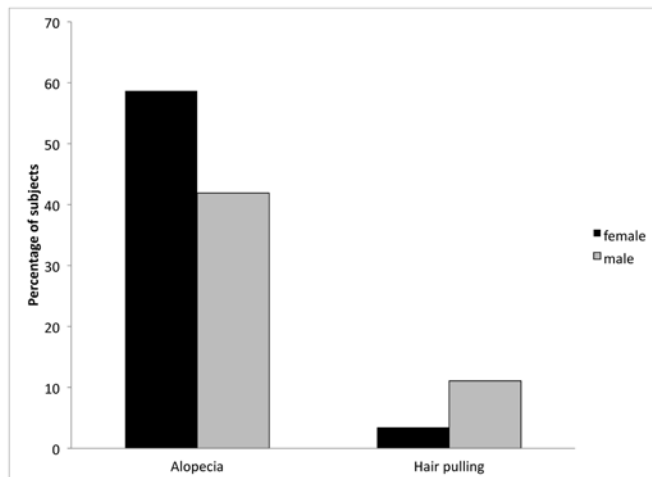
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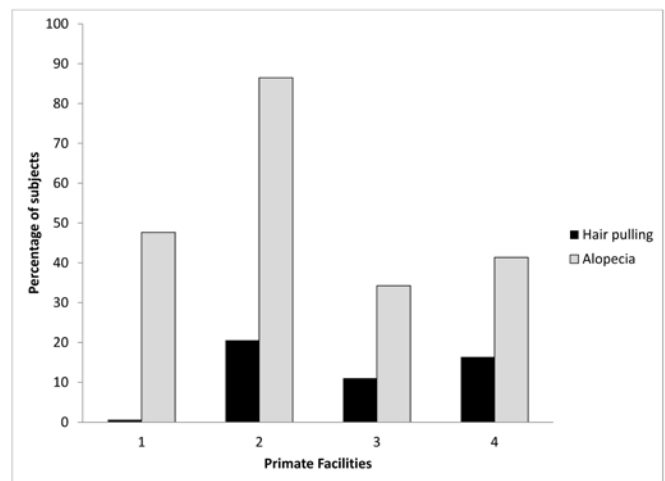
Table 1. Macaques by sex and facility

	Facility				Total
	1	2	3	4	
Female	340	55	93	66	554
Male	290	130	234	50	704
Total	630	185	327	116	1258

**Figure 1.** Hair-pulling and alopecia in male and female rhesus monkeys.

were housed at 4 US National Primate Research Centers (New England, Oregon, Southwest, and Washington; Table 1) and maintained in accordance with the *Guide for the Care and Use of Laboratory Animals*.¹⁰ Subjects were chosen based on their single-housing status. At the time of assessment, they were singly housed in cages appropriate to their size in rooms where they had visual and auditory contact with conspecifics. They were all fed a nutritionally balanced diet supplemented with additional fruit, produce, and food treats. All subjects participated in facility environmental enrichment programs and were provided with perches, novel toys, foraging devices, and novel food items on a regular basis. The 4 primate facilities are all accredited by AAALAC, and all work was approved by the local IACUC.

Procedures. As part of the environmental enhancement program at each primate facility, behavioral management personnel conduct routine behavioral assessments on the singly housed nonhuman primates. Because historical data were used for this study, the exact procedures for these assessments varied slightly across facilities. However, each assessment involved a focal observation conducted by a trained member of the behavioral management team. Observation of each animal lasted either 5 min (facilities 1, 2, and 3) or 10 min (facility 4). During this time, any abnormal behaviors, including hair-pulling (that is, plucking out one's own hair with either the hands or teeth), exhibited by the subject was recorded. Assessments were conducted annually (facility 1), 3 times a year (facility 3), or quarterly (facilities 2 and 4). Because of this difference in assessment frequency, the number of formal observations conducted on the animals varied across facility. However, any hair-pulling observed outside of the formal behavioral assessments was recorded also. These additional observations were conducted during daily routine husbandry procedures, enrichment provisioning, or health checks, thus generating additional reports of the behavior. A macaque was categorized as a hair-puller if it was observed

**Figure 2.** Hair-pulling and alopecia across the 4 primate facilities.

to pull hair either during behavioral assessment or at anytime outside of the assessment period.

In addition to behavior, the animal's hair coat was scored during the formal behavioral assessments (facilities 1, 2, and 4) or separately, but within 2 mo of, the assessment (facility 3). If any hair loss was noted on any part of the animal's body at this time, the macaque was categorized as having alopecia. In all cases, the alopecia score coinciding with the most recent behavioral assessment for each animal was used for this study. Shaving for clinical purposes occurred infrequently. However, when it did occur, locations identified as having been shaved were not considered to be alopecic. In addition, none of the subjects were on projects that were known to result in hair loss.

Data analysis. χ^2 analyses were conducted to determine sex- and facility-associated differences in alopecia and hair-pulling. In addition, a χ^2 analysis was performed to identify an association between alopecia and hair-pulling. Logistic regression analysis of the data was conducted to identify potential risk factors associated with the occurrence of alopecia, with sex and hair-pulling as predictors. Estimates of the total variance in alopecia explained by sex and hair-pulling were obtained from three pseudo R^2 measures developed for logistic regression (McFadden, Cox and Snell, and Naglekerke). Differences were considered to be statistically significant when the P value was less than 0.05. Systat version 13 (Systat Software, Chicago, IL) was used to perform all analyses.

Results

Overall, 49.3% of the rhesus macaques showed some form of hair loss, with females (58.7%) exhibiting more alopecia than males (41.9%; $\chi^2_1 = 34.845$, $P < 0.001$; Figure 1). In addition, significant differences were reported across the 4 facilities, with alopecia ranging from 34.3% to 86.5% of the facility population ($\chi^2_3 = 135.604$, $P < 0.001$; Figure 2). Even though the extent of alopecia varied across primate centers, in centers reporting a sex-associated difference, female macaques consistently had higher levels of alopecia than did males (Table 2).

Fewer macaques were reported to hair-pull than to have alopecia. Of the 1258 subjects, 97 (7.7%) were reported to hair-pull at some point either during or outside of the behavioral assessments. There was a sex-associated difference in hair-pulling, with significantly more male macaques (11.1%) being reported as hair-pullers than females (3.4%; $\chi^2_1 = 25.496$, $P < 0.001$; Figure 1). As with alopecia, there was a significant facility-associated difference, with hair-pulling reports ranging from 0.6% to 20.5%

Table 2. Analysis of alopecia and hair-pulling by sex and facility

Facility	Frequency of formal assessments	Alopecia: females > males	Hair-pulling: males > females	Alopecia: hair-pullers > nonhair-pullers
1	annually, 5 min	$\chi^2_1 = 43.261, P < 0.001$	nonsignificant	nonsignificant
2	quarterly, 5 min each	nonsignificant	$\chi^2_1 = 8.442, P < 0.005$	$\chi^2_1 = 4.845, P < 0.05$
3	3 times per year, 5 min each	$\chi^2_1 = 11.533, P < 0.005$	$\chi^2_1 = 8.036, P < 0.01$	$\chi^2_1 = 8.154, P < 0.005$
4	quarterly, 10 min each	nonsignificant	nonsignificant	nonsignificant

of the primate center populations ($\chi^2_3 = 104.367, P < 0.001$; Figure 2). However, even though rates of hair-pulling varied across primate centers, in centers reporting a sex-associated difference, hair-pullers were significantly more likely to be male than female (Table 2).

Although a majority of macaques with alopecia had no report of hair-pulling, there was a significant association between hair-pulling and alopecia (Figure 3). Animals that hair-pulled were significantly ($\chi^2_1 = 22.014, P < 0.001$) more likely to have alopecia than were those that did not hair-pull, and this trend remained consistent across primate centers that reported a significant difference (Table 2).

Logistic regression analysis revealed that sex and hair-pulling were significant predictors of alopecia. The predicted odds of female macaques having alopecia was 2.28 times that of male macaques ($b = 0.825, P < 0.001$), and the predicted odds of alopecia in a hair-pulling macaque was 4.42 times that of an animal with no record of hair-pulling ($b = 1.487, P < 0.001$). There was no interaction between sex and hair-pulling ($b = -1.050, P > 0.05$). Estimates of the total variance in alopecia explained by sex and hair-pulling were low and ranged from 4% to 7%.

Discussion

Hair loss is prevalent in the 4 primate centers, with an average of almost 50% of the captive population of rhesus macaques. However, the percentage in this study includes all instances of alopecia, ranging from small patches of hair loss to hair loss over the entire body. These percentages may not reflect numbers reported at other facilities that may have more stringent criteria. For the current study, the alopecia score was based on a single observation, a ‘snapshot’ of hair loss exhibited by the animal at a single point in time. Longitudinal studies of lifetime instances of alopecia likely would result in higher overall percentages. Although we do not report severity, most alopecia in nonhuman primates is mild, often consisting of a few small areas of coat thinning or hair loss.^{5,15,19}

Alopecia has been shown to differ by both the sex of the animal and by the facility. In the present study, female macaques exhibited more hair loss than did males. Although some studies have reported more alopecia in males,¹³ a higher prevalence of alopecia in females has been reported in both macaques^{12,19} and baboons¹⁵ and may be due, in part, to reproductive condition.^{5,7,13} For example, in a group of socially housed rhesus monkeys, hair loss was noted through the gestation period, with regrowth occurring after parturition.⁷ In the present study, the subjects were singly housed at the time of the alopecia scoring, and therefore the chance that they were pregnant was low, although some may have recently been moved from breeding groups or from a male partner. The facility-associated differences in the occurrence of alopecia may reflect a number of factors, including climate and differences in housing condition. Variables such as amount of sunshine, humidity, and day length have all been correlated with hair coat condition,¹⁹ and although housing history was not analyzed in the current study, housing

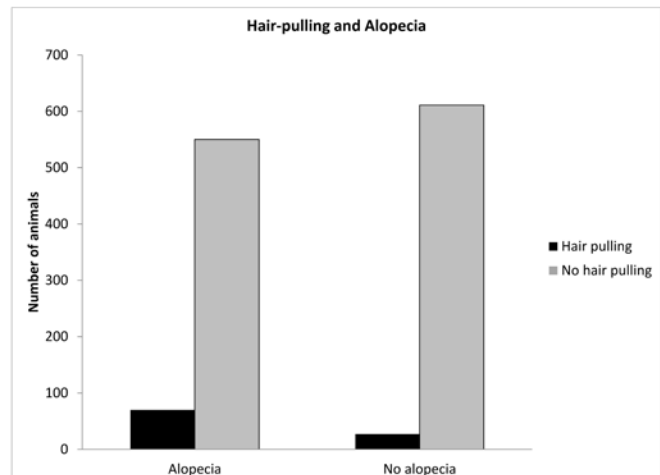


Figure 3. The association between hair-pulling and alopecia.

has been shown to affect alopecia. In one study conducted at the New England Primate Research Center, rhesus monkeys born indoors had a higher risk of developing alopecia than did those born in outdoor facilities.¹² Housing can also affect levels of alopecia within a facility. For example, rhesus monkeys housed in outdoor enclosures with a gravel substrate had a poorer coat quality than did those living in enclosures containing grass,⁴ and this difference may be due to a greater amount of time spent grooming by animals in the gravel enclosures. In addition, macaques housed outdoors had better coat conditions than those housed indoors or in mixed indoor-outdoor housing.¹⁹ In the 2 facilities reporting a sex-associated difference, female macaques had higher levels of alopecia than did males, yet the facilities differed in overall levels of alopecia.

The incidence of hair-pulling was significantly lower than that of alopecia, averaging just under 8% of the population and further demonstrating that hair-pulling is not the sole, or even a major, cause of alopecia. Whereas alopecia was observed significantly more often in females, hair-pulling occurred significantly more often in males. This increased tendency of male macaques to display hair-pulling (in addition to other abnormal behaviors) has been reported previously,¹⁴ but the cause of this sex-associated difference has yet to be identified. Hair-pulling also differed by facility, ranging from less than 1% to 20.5% of the population. These facility-associated differences in hair-pulling may reflect differences in animal management and observation procedures. For example, duration of single-housing can affect the incidence of hair-pulling; the longer an animal is singly housed, the more likely it is to hair-pull.¹⁴ In addition, how frequently macaques were observed differed across facilities. For example, facility 2 conducted behavioral assessments on a quarterly basis, whereas facility 1 conducted annual assessments. Although hair-pulling could be reported by both care and clinical staffs at any time throughout the year, this difference in frequency of formal observation sessions may have played a role in facility-associated differences. However,

despite these differences in observation and reporting, the 2 facilities reporting a significant sex-associated difference reported higher levels of hair-pulling in male macaques.

Hair-pulling and alopecia are strongly associated—macaques that hair-pulled were more likely to exhibit hair loss—but that association does not mean all alopecia is caused by hair-pulling. In the present study, a significant number of macaques with hair loss were not observed to pull out their hair, and hair-pulling explained only a small portion of the total variance in alopecia. This trend was consistent across primate centers. Therefore, the behavior of hair-pulling and the condition of an animal's coat may not be as closely associated as believed previously; the variables associated with alopecia are much more complex.¹³ As reviewed previously,¹⁷ alopecia can be caused by a number of factors. When investigating cases of alopecia in macaque monkeys, hair-pulling is just one of many etiologies to consider.

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