Effects of Castration on Grooming in Goats

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MOORING, M. S., A. J. GAVAZZI AND B. L. HART. Effects of castration on grooming in goats. PHYSIOL BEHAV 64(5) 707–713, 1998.—In African antelope and North American cervids, breeding males during the rut engage in less oral self-grooming, and harbor a greater density of ticks, compared with conspecific females and non-breeding males. The purpose of this study was to experimentally test the proposition that down-regulation of self grooming in some male bovids occurs via the direct or indirect action of testosterone. Domestic dairy goats (Capra hircus) were used as a model. In Experiment 1, comparative observations conducted on twelve gonadally intact male goats (bucks), nine males castrated at 3 weeks of age (wethers), and twelve intact females (does) supported the prediction that the grooming rate of intact males would be depressed relative to wethers and does. Bucks oral groomed at one-third and one-fourth the rate of wethers and does, respectively, and they scratch groomed half as much as does. There was no significant difference between wethers and does in oral or scratch grooming rates. Experiment 2 involved castration of eleven bucks from Experiment 1, followed by 2 months of observation. Similar to the pattern of other testosterone-dependent behavioral changes after castration in adult males, there was a good deal of variation in the individual grooming response of males to castration, with increases in grooming taking 2 to 8 weeks to be manifested in ten of eleven goats. Overall, castrated males oral groomed about 3 × above their intact rates, supporting the prediction that castration removes testosterone-mediated suppression of grooming. This is the first example of alteration of grooming behavior in males by gonadal androgen, and the first demonstration of enhancement of any mammalian behavior by removal of gonadal androgen. © 1998 Elsevier Science Inc.

FOR MANY mammalian species, including African antelope and North American cervids, grooming is one of the most frequently and regularly performed behavior patterns. In African antelope, depending on species, a bout of oral grooming (seven to eleven grooming episodes per bout) is delivered on average every 4–10 min throughout the day, resulting in up to 1,600 oral-grooming episodes per 12-h day (15, 28). An important function of grooming is control of ectoparasites, and experimental studies on several species in which grooming was restricted have provided evidence for the effectiveness of grooming in removing ectoparasites (13). The most recent study on bovids, utilizing captive impala (Aepyceros melampus), found that the application of neck harnesses, which partially prevented oral self-grooming, resulted in 20 × more adult female ticks on restrained animals than on impala wearing control harnesses that permitted grooming (32).

While grooming confers benefits in terms of ectoparasite control, one can also point to costs of oral grooming, including attrition of the lower incisors when these are used in grooming (25, 26) and distraction from vigilance for predators or conspecifics when the head is turned during grooming, blocking vision from the front and the side not being groomed (29). These benefits and costs of grooming, especially distraction from vigilance, are evident from field observations on several species of African antelope (15, 30, 33). In breeding males, distraction from vigilance during the time that the head is oriented toward the pelage would compromise the territorial male’s success at detecting rival males or wandering females; females need only a few seconds to bolt from a territory or be “hijacked” by a competing male. Accordingly, the prediction that territorial males will groom significantly less than females has been supported in observations on Thomson’s gazelle (Gazella thomsoni), Grant’s gazelle (G. granti), wildebeest (Connochaetes gnu) and impala, in which males groomed at only one-third to one-half the rate of females and non-breeding males (15). A corollary is that such males should carry more ectoparasites, a prediction verified in two studies on impala in Zimbabwe where territorial males were found to carry up to 6 × more adult ticks than females or bachelor males (30, 33). In North American cervids, where rutting males, like their African bovid counterparts, must remain vigilant to fend off rival males and acquire estrous females, breeding males (white-tailed deer, Odocoileus virginianus; moose, Alces alces) carried twice as many ticks as females (8, 24).

There are two models for the regulation of grooming in bovids: 1) the stimulus-driven model in which grooming is directed to a specific area of the body in response to an irritation or itch (as from an ectoparasite bite); and 2) a type of programmed grooming in which grooming bouts are delivered to an animal’s body on a more or less regular basis in response to a loosely-running, endogenous...
at a frequency more similar to that of females than gonadally intact practices. Such animals, called wethers, would theoretically groom males that are castrated soon after birth as part of husbandry (Fig. 1). With dairy goats, one also has the opportunity to observe using the lower incisors in bouts of upward scraping movements domestic goats oral groom in the same way as African antelope, gonadally intact males groomed less than intact females and that stimulation or begin to feed.

ectoparasites, removing them even before they produce cutaneous grooming as opposed to the stimulus-driven model. The utility of (30,32) and habitat constraints (17)—support the programmed analysis of body size (15,31), sex (15,30,33), exposure to ticks (30,32) and habitat constraints (17)—support the programmed grooming as opposed to the stimulus-driven model. The utility of programmed grooming is that it anticipates the occurrence of ectoparasites, removing them even before they produce cutaneous stimulation or begin to feed.

Within the context of these two models for the control of grooming, there are two explanations for reduced grooming by breeding males. One is that the reduction in grooming is due to the action of testosterone in down-regulating programmed grooming rate, as recently modeled (14). Alternatively, grooming could be reduced because of the competing behavioral demands associated with rutting. Arguing against the latter explanation are observations on territorial male antelope which have no females on their territory and few current competing demands of rutting activity, but which still have markedly reduced grooming rates (15,33).

A direct test of the hypothesis that testosterone down-regulates grooming activity in those species in which grooming is sexually dimorphic is to observe the effects of castration on males. Because of the necessity to perform baseline behavioral observations before castration and closely monitor changes in grooming behavior in the weeks after castration, it is necessary to conduct such an experiment on captive animals. In preliminary work, we had found that in domestic dairy goats (Capra hircus), as in African antelope, gonadally intact males groomed less than intact females and that domestic goats oral groom in the same way as African antelope, using the lower incisors in bouts of upward scraping movements (Fig. 1). With dairy goats, one also has the opportunity to observe males that are castrated soon after birth as part of husbandry practices. Such animals, called wethers, would theoretically groom at a frequency more similar to that of females than gonadally intact males. Thus, goats are an ideal subject for examination of the hypothesis.

In Experiment 1, we performed systematic, focal animal observations on grooming rates among gonadally intact males, wethers (castrated at 3 weeks), and gonadally intact females. In Experiment 2, we used the observations of grooming rate in the intact males as a baseline for comparisons after castration. The latter experiment explored concepts in mammalian behavioral endocrinology that have not been tested previously, namely: 1) the effect of an androgen on grooming behavior; and 2) the enhancement of a sexually dimorphic behavioral pattern by removal of a gonadal hormone rather than its activation, as is typically seen.

There has been one study of the effects of castration on reproductive behavior in male goats, revealing that changes in mating behavior after castration are very prolonged, and that there are major individual differences in response to castration (16). Thus, Experiment 2 was designed to take into account individual grooming differences in response to castration and to record such differences over a 2-month period after castration. Because castration can also affect aspects of rutting behavior, such as interactions with other males and attention to females, the study design took into account the necessity to monitor changes in these behavioral patterns so as to address the issue of whether declines in grooming could be attributed simply to reduced rutting behavior and other inter-male interactions allowing more time for grooming. The latter issue was addressed by activity scan sampling carried out during the focal animal observations on grooming behavior. To allow the full range of inter-male interactions, the experimental animals were housed as a group rather than individually.

METHODS

Study Site and Subjects

These studies were conducted at the University of California, Davis Dairy Goat Facility from January to May 1997. Subjects were twelve 2-year-old gonadally intact male goats (“bucks”). Bucks were housed in a 140 × 192.5 m pasture pen containing two sheds for use in inclement weather, and were provisioned with oat hay (Avena sativa) and water. Goats also grazed ad lib. on pasture grass in the pen. All goats and their pens were free of ticks and other ectoparasites. Comparative observations were made on twelve 1- to 2-year-old intact female goats (“does”) and nine 1- to 2-year-old wethers castrated at 3 weeks of age. Does were housed in either a 16.4 × 59.1 m or 21.9 × 87.5 m pen and wethers in a 59.1 × 114.8 m; all pens had shed refuges. Does and wethers were fed alfalfa hay (Medicago sativa) and provided with water. Goat breeds were primarily Alpine or Alpine crosses with other breeds (Toggenberg, Saanen, La Mancha, Nubian, or Angora). All goats had been raised at the Dairy Goat facility and were accustomed to human handling.

Behavioral Observations

Goats oral groom with upward scraping motions of their lateral (lower) incisor-canine teeth against the pelage and scratch with the hoof of the hindleg. Oral grooming is directed to all parts of the body except the head and neck, whereas scratching is directed to the head, neck, shoulder, belly, foreleg, or flank. Each grooming movement (teeth scrape or hoof scratch) was an “episode,” with a connected series of episodes on the same body area being a “bout.” Observations were by focal animal sampling (4), with each focal animal followed for a 20-min observation session. All bouts and episodes of oral and scratch grooming, as well as the target body area, were recorded during a focal session, with instantaneous scan sampling of activity made every 2 min to determine activity budgets (4). Activities recorded were classified as oral grooming, scratching, rubbing (rubbing a body region against a stationary object), feeding/drinking, moving (walking, running), inactive (standing, ruminating), reproductive (mounting another male, performing flehmen), and agonistic (head butting, chasing another male). Observations were conducted 5 days per week. Goats were ear-tagged with their identification numbers and were also distin-
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Grooming increased to a criterion level, established by a two-tailed Mann–Whitney test showing an individual’s oral grooming rate (both bouts, 10% for wethers and does). The mean grooming rates were estimated for each animal. Due to constraints in the number of goats that could be individually observed on a daily basis, it was not possible to observe each group of goats during the same time frame, and, therefore, we obtained grooming rates of bucks first (January), wethers second (February), and does third (April–May). Although there were daily and weekly temperature fluctuations during this time, the only environmental variable that seemed, in preliminary observations, to affect grooming rate was rain, and no observations were conducted during rain. The mean ambient temperature increased, of course, over the duration of the experiment, but the hot season of July and August was avoided. As a precaution, this scheduling procedure was biased against supporting our prediction that does and wethers will groom more than bucks because in unpublished observations we have noted a tendency for antelope and goats to lie down during very hot times of the day and engage in less grooming.

Experiment 2: Grooming Rates of Intact versus Castrated Males

Eleven of the twelve intact males from Experiment 1 were available for this experiment. Castration was performed shortly after observations of baseline grooming rates. The castrations were performed at the campus Veterinary Medicine Teaching Hospital following the customary procedure in which, using sterile technique, the scrotum was incised, the spermatic cord transected and ligated, and the testicles were removed. The incision was allowed to heal by secondary intention, i.e., leaving it open to allow for drainage. Following castration, goats were kept in a straw-bedded pen inside the goat barn for 2 weeks to allow for recovery, then returned to their outdoor pasture pen.

Post-surgical observations of castrates were conducted from February to April, and followed the same methodology as described for Experiment 1. The subjects were observed in 2-week blocks (ten 20-min focal observations per animal) until grooming increased to a criterion level, established by a two-tailed Mann–Whitney test showing an individual’s oral grooming rate (both bouts and episodes) during a 2-week block had become significantly greater (p < 0.05) than during the baseline period. Animals that reached the criterion were dropped from post-castration observations, and the remainder were observed for another 2-week block. At the end of four 2-week postoperative periods (8 weeks), the study was terminated.

Blood Sampling

Although the study began after the normal breeding season, blood samples were taken to establish testosterone levels of males. Three jugular venous blood samples (5 mL) were taken of each male during the intact baseline observations in January to determine intact serum levels of testosterone. Serum was removed from blood samples by centrifuging at 3500 rpm for 10 min and analyzed by standard radioimmunoassay procedures (41). The mean of the three samples was taken as the intact serum testosterone level for individual males. Blood samples were similarly taken after castration to confirm very low levels of testosterone in postcastration males.

Data Analysis

Oral and scratch grooming are reported as bouts and episodes delivered per 20 min. Statistical analysis of data made use of non-parametric procedures (43). For comparisons among bucks, wethers, and does we used the Kruskal–Wallis ranked ANOVA with Scheffe multiple comparisons. The Wilcoxon signed-rank test was used for pairwise comparisons between intact baseline and postcastration treatments, using each animal as its own control. All tests were two-tailed with significance set at 0.05.

RESULTS

Experiment 1: Grooming Rates of Bucks, Wethers, and Does

Grooming rates. Does and wethers delivered four to five oral bouts, comprising 60–80 episodes, per 20-min observation period, which was about 4 × the oral grooming rate of bucks (Fig. 2). Kruskal–Wallis ANOVA revealed a significant difference in oral grooming rate among bucks, wethers, and does (bouts, n = 33, H = 18.3, p < 0.0001; episodes, n = 33, H = 15.6, p < 0.0004), and Scheffe multiple comparisons showed that bucks groomed less than does (p < 0.0001) and wethers (p < 0.02), but that the oral grooming rate of does and wethers did not differ significantly. Scratch grooming rate also differed significantly among sex groups (Kruskal–Wallis: bouts, n = 33, H = 11.1, p < 0.004; episodes, n = 33, H = 9.4, p < 0.009), with does delivering 1.5 bouts and 20 episodes per 20 min, more than 2 × that of bucks (Fig. 2) and also significantly different according to Scheffe multiple comparisons (p < 0.005). Wethers did not scratch significantly more than bucks, and scratch grooming rate of does and wethers was not significantly different. Grooming episodes per bout did not differ significantly among groups (mean episodes per bout: oral grooming, 14.5; scratch grooming, 15.8).

Activity scans. Consistent with the results of focal observations, ANOVA of scan sampling data showed that bucks spent one-third less time engaged in oral grooming than does (bucks, 1.2%; wethers, 3.1%; does, 3.0%; Kruskal–Wallis: n = 32, H = 7.42, p < 0.02; Scheffe multiple comparisons: p < 0.02). By this more limited measure of grooming, wethers did not differ significantly from either bucks or does, and there was no significant difference among groups in the amount of time spent scratching (H = 1.09, p > 0.5) or rubbing (H = 4.00, p > 0.13). As expected, bucks spent more time engaged in reproductive behavior compared with does (H = 10.32, p < 0.006; Scheffe: p < 0.003), but wethers were not significantly different from bucks or does. Nonetheless, bucks only spent 1.2% of their activity time in reproductive behavior (24 s out of a 20-min observation period), compared with 1.0% for wethers and 0% for does. There was no difference in agonistic behavior among groups (H = 4.05, p > 0.13), which comprised 1–2% of activity time.

Experiment 2: Grooming Rates of Intact versus Castrated Males

Serum testosterone. The median precastration level of serum testosterone was 4.4 ng/mL, and, as expected, the testosterone level after castration was close to zero (median = 0.015 ng/mL), a difference that was highly significant (Wilcoxon: n = 11; Z = 2.93, p < 0.003).

Grooming rate. The mean rate of grooming increased over the
course of the experiment in ten of eleven castrates, with nine reaching the within-subject Mann–Whitney criterion before the end of the experiment. The pattern of change in frequency of grooming bouts for each goat is shown in Fig. 3 (the pattern for episodes was similar). Two of the goats reached criterion during the first 2-week block, five reached criterion in the second 2-week block, and two reached criterion during the fourth 2-week block. Of the two goats that never made the criterion, the mean oral grooming rate of one male (5083) was greater than his intact baseline rate for all the postcastration 2-week blocks, with the greatest increase during the first block. The one castrate that never oral groomed more than when intact (5080) had an intact baseline oral grooming rate that was at least twice as high as any other goat; his oral grooming rate never changed significantly throughout the study. The mean (±SD) number of bouts and episodes of oral grooming delivered per 20 min by each goat during the intact baseline and post-castration treatments is shown in Table 1. The grooming rate reported for the castrated treatment is either the mean of the ten 20-min observations during the 2-week block when grooming rate reached criterion, or, for the two goats that never made criterion, the mean of all 40 postcastration 20-min observations. Of the nine males who reached the criterion, post-castration rates of oral grooming were between 2 and 14× greater than intact rates (Table 1).

The overall mean rate of oral grooming was over 3× greater during the post-castration treatment compared with intact rates, and highly significant (Table 2). The number of oral grooming bouts delivered per 20 min by the eleven males during intact baseline and for each 2-week period after castration is illustrated in Fig. 4 (for goats that reached criterion before weeks 7–8, grooming rate in subsequent weeks was calculated at the criterion level). Besides oral grooming more frequently, male goats delivered more oral episodes per bout after castration (mean ± SEM = 19.9 ± 1.2) than during intact baseline (15.6 ± 1.6) (Wilcoxon: n = 11, Z = 1.96, p < 0.05). Although the subjects delivered more scratch bouts after castration than when intact (Wilcoxon: n = 11, Z = 2.67, p < 0.008), there was no significant difference in scratch episodes per 20 min (n = 11, Z = 1.78, p < 0.08), nor was there any significant difference in scratch episodes per bout between the intact and post-castration treatments (Wilcoxon: n = 11, Z = 0.44, p > 0.6).

Activity scans. Consistent with the focal observations, the activity scan data (Table 3) showed that castrated males spent twice as much of their daily activity budget engaged in oral grooming as they did before castration (Wilcoxon: n = 11, Z = 1.96, p < 0.05). Rubbing, mostly of the head, also increased compared with intact activity rates (Z = 2.81, p < 0.005). According to activity scans, the amount of time spent scratching did not reach significance (Z = 0.05, p > 0.9). There was no significant difference in feeding and drinking (Z = 1.69, p > 0.09) or lying down and ruminating (Z = 0.71, p > 0.4). Behaviors classified as reproductive (mounting, flehmen), or agonistic interactions with other males comprised 3.3% of the scan times in intact males, and after castration, declined by about 90% (reproductive: Z = 2.39, p < 0.02; agonistic: Z = 2.65, p < 0.008).
EFFECTS OF CASTRATION ON GROOMING

TABLE 1
MEAN (±SD) ORAL GROOMING RATES OF 11 MALE GOATS, INTACT AND FOLLOWING CASTRATION

<table>
<thead>
<tr>
<th>Goat</th>
<th>Oral bouts per 20 min</th>
<th>Oral episodes per 20 min</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Intact</td>
<td>Castrated*</td>
</tr>
<tr>
<td>5011</td>
<td>0.60 (±0.87)a†</td>
<td>3.70 (±3.13)b</td>
</tr>
<tr>
<td>5015</td>
<td>1.30 (±1.06)a</td>
<td>8.60 (±3.32)b</td>
</tr>
<tr>
<td>5074</td>
<td>0.20 (±0.42)a</td>
<td>1.00 (±0.94)b</td>
</tr>
<tr>
<td>5075</td>
<td>1.10 (±0.74)a</td>
<td>5.10 (±3.51)b</td>
</tr>
<tr>
<td>5076</td>
<td>1.40 (±1.08)a</td>
<td>3.30 (±1.64)b</td>
</tr>
<tr>
<td>5080</td>
<td>3.40 (±2.46)a</td>
<td>3.12 (±3.47)a</td>
</tr>
<tr>
<td>5083</td>
<td>1.20 (±1.03)a</td>
<td>2.12 (±1.76)a</td>
</tr>
<tr>
<td>5086</td>
<td>1.70 (±2.06)a</td>
<td>3.80 (±2.66)b</td>
</tr>
<tr>
<td>5088</td>
<td>0.86 (±1.86)a</td>
<td>3.00 (±2.16)b</td>
</tr>
<tr>
<td>5102</td>
<td>0.60 (±0.89)a</td>
<td>4.80 (±4.87)b</td>
</tr>
<tr>
<td>5108</td>
<td>0.50 (±0.97)a</td>
<td>2.50 (±2.12)b</td>
</tr>
<tr>
<td></td>
<td>11.2 (±22.9)a</td>
<td>70.3 (±38.4)b</td>
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<tr>
<td></td>
<td>29.5 (±37.3)a</td>
<td>179.8 (±103.5)b</td>
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<td></td>
<td>1.8 (±3.9)a</td>
<td>22.1 (±43.1)b</td>
</tr>
<tr>
<td></td>
<td>17.0 (±17.6)a</td>
<td>97.6 (±73.3)b</td>
</tr>
<tr>
<td></td>
<td>25.2 (±23.0)a</td>
<td>84.4 (±60.6)b</td>
</tr>
<tr>
<td></td>
<td>79.4 (±71.2)a</td>
<td>59.1 (±85.0)a</td>
</tr>
<tr>
<td></td>
<td>11.8 (±11.8)a</td>
<td>27.3 (±26.7)a</td>
</tr>
<tr>
<td></td>
<td>34.0 (±60.1)a</td>
<td>75.5 (±50.2)b</td>
</tr>
<tr>
<td></td>
<td>8.4 (±19.8)a</td>
<td>40.6 (±32.5)b</td>
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<td></td>
<td>8.8 (±16.1)a</td>
<td>124.7 (±185.5)b</td>
</tr>
<tr>
<td></td>
<td>5.3 (±10.7)a</td>
<td>52.0 (±51.8)b</td>
</tr>
</tbody>
</table>

* Castrated value is the mean for the 2-week block (n = 10 observations) when grooming rate reached the criterion by being significantly greater than intact rate by Mann-Whitney comparison, or (for 5080 and 5083) the mean of all post-castration observations (n = 40).
† Different letters between intact and castrated indicates a significant difference (P < 0.05) by the Mann-Whitney test.

DISCUSSION

In Experiment 1, intact bucks oral groomed at one-third and one-fourth the rate of wethers and does, respectively, whereas there was no significant difference between wethers and does in oral grooming rates. Following castration, bucks of Experiment 2 oral groomed about 3x above their intact rates, supporting the prediction that castration removes testosterone-mediated suppression of grooming. These results are best interpreted in light of what is known about caprine evolution and the natural history of their reproductive behavior. Wild goats are browsers whose natural habitat is on the high mountain ranges of Europe, Asia, and Ethiopia (6). The domestic goat, C. hircus, was domesticated about 8,500 years ago from the wild bezoar goat, C. aegagrus, which itself is most closely related to the ibex, C. ibex (6,18). Behavioral studies of these wild goats can thus be used to infer the ancestral social system of present-day dairy goats. No species in the genus Capra is territorial (39); rather, males exhibit a rigid linear dominance hierarchy in which the oldest males with the largest bodies and longest horns are dominant (9,37,39,40,42). During most of the year, males are either solitary or associate in loose herds, and longest horns are dominant (9,37,39,40,42). During most of the rut, males exhibit one of two reproductive strategies depending upon dominance status (40,42). Dominant males follow and closely guard females, testing their urine, courting them, and threatening other males who venture too near. Subordinate males (or dominant males unable to control a female) may approach females and attempt to mount without courtship, which may lead to scramble competition for matings by several males. Not surprisingly, aggression during the rut is 5x greater than at other times (39,42). Along with courtship and guarding of females, male vigilance rate is also higher at this time (2).

Grooming by goats appears to be an adaptive response to the fitness costs of tick infestation. The effectiveness of oral grooming by goats was shown in one study in which domestic goats, experimentally exposed to lone star ticks (Amblyomma americanum), were stanchioned in headgates to restrain them from grooming; the number of adult ticks that engorged on restrained goats was 77x greater than on unrestrained goats that could groom (21). The oral grooming efficiency of domestic goats reflects the tick challenge that goats are exposed to under pastoral and feral conditions, documented by studies on the tick burdens of goats (e.g., 3, 5, 19, 20).

![Graph](Image)

**FIG. 4.** Mean (± SEM) oral-grooming episodes per 20 min performed by eleven male goats, when intact and during the 8 weeks (four 2-week periods) after castration. Each data point is the mean grooming rate for all goats; for males that reached the criterion level of grooming before Weeks 7–8, rates in subsequent 2-week periods are calculated at the criterion level. On average, castrated males oral groomed 3x more than when they were intact.

TABLE 2
MEAN (±SEM) GROOMING DELIVERED PER 20 Min BY MALE GOATS DURING INTACT BASELINE AND FOLLOWING CASTRATION, AND Z STATISTICS AND P-VALUES FROM THE WILCOXON TEST

<table>
<thead>
<tr>
<th>Grooming rate</th>
<th>Intact</th>
<th>Castrated</th>
<th>Z</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oral bouts</td>
<td>1.17 (±0.26)</td>
<td>3.73 (±0.60)</td>
<td>2.84</td>
<td>0.004</td>
</tr>
<tr>
<td>Oral episodes</td>
<td>21.1 (±6.6)</td>
<td>75.8 (±13.8)</td>
<td>2.68</td>
<td>0.008</td>
</tr>
<tr>
<td>Scratch bouts</td>
<td>0.64 (±0.11)</td>
<td>1.11 (±0.08)</td>
<td>2.67</td>
<td>0.008</td>
</tr>
<tr>
<td>Scratch episodes</td>
<td>12.07 (±3.62)</td>
<td>16.64 (±1.73)</td>
<td>1.78</td>
<td>0.08</td>
</tr>
</tbody>
</table>
34, 35). The costs of tick infestation from blood loss and anorexia have been well documented in studies of cattle, in which a moderate number of ticks on a growing calf may cause a loss in weight gain of 10–44 kg per year, representing up to 3.1 kg of weight loss per engorged tick on an annualized basis (20,22,38,44). In addition to blood loss, goats may suffer from tick-borne diseases such as heartwater, redwater, and anaplasmosis (10,46), tick paralysis to blood loss, goats may suffer from tick-borne diseases such as heartwater, redwater, and anaplasmosis (10,46), tick paralysis.

Despite the importance that grooming in nature has in maintaining low ectoparasite numbers, breeding male goats, like African antelope (15,30,33), groomed less than females, presumably because grooming interferes with rutting activity. Intact bucks in Experiment 1 oral groomed at only one-fourth to one-third the rate of wethers and intact does. Scratch grooming was performed at one-half the rate of does and did not differ significantly from wethers. The reduced grooming, especially noticeable in oral grooming, could come about either through the competing demands of rutting activity or by down-regulation of programmed grooming by testosterone. Evidence for the latter comes from Experiment 2, where male goats increased their rate of oral grooming (both bouts per hour and episodes per bout) to 3× that of intact baseline rates during the 2 months after castration. Scratch grooming bouts per 20 min was also greater, but the difference for scratch episodes per 20 min did not reach significance. As expected, there was a wide variation in individual response to testosterone removal, with elevated grooming taking 2 to 8 weeks to reach criterion in nine of eleven goats, and with the magnitude of the increase ranging between 2 and 14× greater than during intact baseline.

Results from scan samples are also supportive of the direct effect of testosterone. Prior to castration, males spent over twice as much of their daily activity budget moving about and engaging in reproductive and aggressive behavior (15%) than they did after castration (6%). However, intact males still spent 27% of the time inactive. Grooming, which increased after castration from 1.2 to 2.3% of activity scans, could easily have come from the inactive part of the time budget of intact males; a reduction of reproductive and agonistic behaviors would not be needed to allow more time for grooming. Even though grooming may account for 1–2% of a male goat’s time budget, a distraction of 10 s to deliver a bout of about ten oral episodes could be enough to lose a female to competing males in the wild.

Goats of temperate regions are seasonal breeders and testosterone concentrations in males undergo seasonal fluctuations, with the highest concentration in September (1,7). The fact that testosterone influences grooming rate opens the possibility that grooming rates could increase during the nonbreeding season, allowing the goats to more readily remove ectoparasites and restore the condition of the pelage.

The effects of castration uncovered here probably apply to a variety of promiscuously breeding African antelope and North American cervids. As mentioned in the introduction, several lines of evidence support the programmed grooming model for the control of grooming bouts in antelope. Testosterone could influence the grooming rate by acting on the endogenous generator responsible for programmed grooming, perhaps by a neuropeptide intermediary such as vasopressin, which is known to influence grooming in rodents (27) and primates (45).

This study is the first example of alteration of grooming behavior in males of any species by gonadal androgen. One would expect such alterations only where the grooming rate is shown to be sexually dimorphic. Although female gonadal hormones are known to suppress behavioral events (e.g., estrogen and food intake; progesterone and sexual behavior), this is also the first demonstration of enhancement of any mammalian behavior by removal of gonadal androgen, which typically is thought of as activating male sex-typical behavior.

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