

Title: Factors regulating steroid hormones in Japanese macaques and orangutans
ニホンザルとオランウータンにおけるステロイドホルモンの動態を調節する要因
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Abstract

The ability to determine hormonal profiles of animal populations can help to monitor reproductive status, physical fitness and physiological responses to environmental changes. In this study, I examined steroid hormones in Japanese macaques (*Macaca fuscata*) and orangutans (*Pongo pygmaeus*), in order to determine the potential factors that influence hormonal levels, to clarify their mechanism of biological action in physiological responses, and to test their reliability in monitoring reproductive state and stress levels using noninvasive techniques. I conducted hormonal analyses using enzyme immunoassay for determination of fecal dehydroepiandrosterone-sulfate (fDHEAS), fecal glucocorticoids (fGC), fecal estrogens (fE), fecal progesterone (fP) and fecal testosterone (fT). Hormonal concentrations were analyzed as function of age, reproductive state (pregnancy, lactation, castration), environment (housing condition, season, temperature) and behavior (dominance rank, aggression, grooming). Age influenced fDHEAS in both Japanese macaques and orangutans, but in different ways. Japanese macaques have a linear decrease in fDHEAS with age, while orangutans have a significant increase between the juvenile and adolescent stages, a phenomenon known as adrenarche. In both species, fGC and fDHEAS increased with acute stress, but a delay between fGC and fDHEAS peak of one-day suggests that DHEAS increases in response to GCs as an antagonist, to modulate the stress response. Neither dominance rank nor season influenced fDHEAS in female Japanese macaques, but fGC was higher during the mating season than the birth season in both males and females. Additionally, fT concentrations rose during the mating season in intact male Japanese macaques, and it was significantly associated with their dominance rank. In castrated males, there was no association of the low levels of fT with dominance

rank, but rank correlated with age. Castrated males were less aggressive than intact males, but there was no difference in grooming time. In intact males, fGC concentrations were negatively associated with grooming time, indicating that males ameliorate stress levels by spending time in affiliative social interactions. Pregnant Japanese macaques and orangutans at late gestation have high fDHEAS concentrations due to fetal adrenal, to provide estrogens for the mother. Hence, fDHEAS did not increase at late gestation in stillbirth cases in Japanese macaques, whereas fE and fP remained elevated above baseline levels. On the other hand, early abortion detected by ultrasonography resulted in a drop of both fE and fP concentrations to pre-pregnancy levels in one Japanese macaque. In orangutans, fGC levels were higher in morning than afternoon samples, but this effect was not observed in Japanese macaques. There was a significant increase in fGC levels and the GC/DHEAS ratio during the first year of orangutan lactation, indicating that the first year is the most energetically costly for the mother. The GC/DHEAS ratio was significantly higher in infants (<5 years old) than adolescents and adults, suggesting that the low levels of DHEAS in early ages might be associated with a developing immune system. Results indicate that dehydroepiandrosterone-sulfate (DHEAS), a poorly studied adrenal steroid, plays major roles in female reproduction and stress regulation, and it should be given more attention. The GC/DHEAS ratio can provide an efficient index of physiological stress, and a concomitant analysis of 'female sex steroids' and DHEAS during pregnancy is useful for monitoring primate gestation. In male reproduction, the association between 'stress hormones' and 'male sex steroids' is an important index for analyzing the complex relationship between hormones and behavior, and help in the understanding the dynamics of primate social interactions. These methods are relevant in studies of wild populations, to estimate fertility rates, population growth, survivability, ability to adapt in challenging environments, and for developing strategies of population control.