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Dominance, Testosterone, and Cortisol

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Synonyms

Competition; Contests; Hierarchy; Sex steroid hormones; Social status; Status; Stress hormones

Definition

Testosterone and cortisol are steroid hormones that have effects on dominance behavior and are in turn influenced by dominance-related social interactions.

Introduction

Dominance status is an important factor in the structuring of many animal and human societies. Dominance is the state of having high social status relative to one or more group-mates, who react submissively to dominant individuals. High status within hierarchical societies provides important benefits to individuals, including priority of access to resources, enhanced influence over subordinates, and ultimately, increased fitness. Lower-ranking individuals are therefore often motivated to improve their position in the hierarchy, whereas higher-ranking individuals strive to maintain their current status. Dominance relationships are often established by fight or threat displays, perhaps most commonly observed during agonistic competitive interactions between group-mates. Dominance displays also function to maintain social rank, once it has been acquired.

Research into the biological factors that affect dominance in animal and human groups suggests that dominance behavior is importantly influenced by two steroid hormones, testosterone (T), a reproductive hormone, and cortisol (C), a stress hormone; concentrations of both these hormones can be measured in blood, saliva, urine, feces, or hair. Two axes in the body, the hypothalamic–pituitary–gonadal axis and the hypothalamic–pituitary–adrenal axis, produce T and C, respectively; each of these axes inhibits the other at several different levels. Together these axes create a complex network regulating aggressive and dominance behavior, although the direction and strength of these hormonal influences are still being assessed. Several hypotheses have been put forward to explain the relationship between dominance and these hormones in a wide variety of animals.

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Cortisol and Dominance

The relationship between C and social dominance varies both across and within species (Creel et al. 2012). Several studies have indicated that socially dominant animals have relatively low concentrations of C, whereas subordinate individuals have relatively high C levels. Often, these differences are particularly striking during times of social instability. In other species, however, dominant individuals have elevated C concentrations compared to those in subordinate animals. Thus, in some cases, it is stressful to be at the top of the social ladder, and in other cases, being at the bottom of the hierarchy is stressful. These differences probably reflect species-specific factors such as social organization, stability of the hierarchy, resource allotment, frequency of agonistic and conciliatory behaviors, and the ability of subordinate animals to avoid dominant individuals (Sapolsky 2005).

The Challenge Hypothesis

The "challenge hypothesis" (Wingfield et al. 1990) was originally proposed to explain intra- and interspecific variation in T secretion in birds in relation to aggressive, sexual, and parental behavior. Here we will focus on dominance and aggressive behavior, about which the challenge hypothesis predicts that behavioral stimuli and social context can alter endogenous hormone concentrations. Behavioral cues, such as territory establishment, agonistic "challenges" from males, and sexual behaviors from females, stimulate the secretion of T. In turn, this increase in T leads to a rise in territorial and mate-guarding aggression. By adjusting T production to the social environment, individuals can exhibit flexible behavioral responses that fit the specific challenge and can also avoid the fitness-reducing costs associated with chronically elevated T levels. A recent meta-analysis found that T was positively correlated with both dominance and aggressive behavior in mammals, although there was no strong pattern when observed across the diverse mating and parental care systems of all vertebrate taxa (Hirschenhauser and Oliveira 2006).

Archer (2006) applied the challenge hypothesis to humans, reasoning that T levels should increase in any competitive situation, particularly in males. In Archer's meta-analysis, both men and women demonstrated a small but positive association between T and aggression, and a larger positive correlation between T and measures of dominance behavior such as toughness, leadership, and aggressive dominance.

The Biosocial Model of Status

Focusing on humans and other primates, the "biosocial model of status" supplements the challenge hypothesis by making explicit predictions regarding T in relation to changes in status (Mazur 1985). Like the challenge hypothesis, this model predicts that T concentrations change during competitive interactions, increasing in winners and decreasing in losers. T should rise shortly before a competitive encounter, increase further in winners at the end of the competition or after a rise in status, and decline in losers or after a reduction in status. Feedback between T and the dominance outcome reinforces a continuation of that behavior, such that these changes in T influence an individual's future competitive behavior. Thus, this model suggests a relationship of mutually reinforcing feedback between T concentrations and social dominance.

Hormonal Correlates of Competition

Winner and/or loser effects have been observed across a wide range of animal taxa. Individuals that have recently won generally exhibit more aggressive behavior toward a new opponent and have a better chance of winning again (the winner effect), whereas individuals that have recently lost frequently display more submissive behavior and have a higher likelihood of losing again (the loser effect) (Hsu et al. 2006). In many species, the outcome of the competition influences T concentrations, with increased levels in winners and reduced levels in losers (Hirschenhauser and Oliveira 2006). In some species winning a contest is not

sufficient to increase the probability of winning future contests unless the victory is associated with an increase in T (Carré and Olmstead 2015). Evidence for the physiological basis of the loser effect is more variable, although elevated levels of C are often discovered in individuals that have recently lost a fight (Hsu et al. 2006).

In humans, T rises in anticipation of a competition and increases during competition; these increases in T are higher during sports competitions than during nonphysical forms of competition (Archer 2006). Athletic competitions are usually also associated with an increase in C in both men and women, regardless of the competition outcome. Winning an athletic competition is associated with an increase in T in both sexes across a variety of sports, although there is no consensus on the effects of losing on T (Casto and Edwards 2016).

However, the winner-loser effect is much more variable when evaluated across all types of human competition, from laboratory paradigms to political elections, including athletics. In a recent review, Carré and Olmstead (2015) found that, although many studies reported that winners had elevated T levels relative to losers, nearly as many studies failed to find this effect; other reviews have found similarly inconsistent results in regard to C (Casto and Edwards 2016). This heterogeneity in results is possibly due to individual differences in personality and contextual differences between competitions. In humans, the T response to competition is more important than the actual contest outcome in predicting future competitive and dominance behavior. Thus, a postcontest rise in T predicts increased competitive behavior in the future, whereas a decrease in T predicts less competitive behavior in both winners and losers alike (Carré and Olmstead 2015).

The Dual-Hormone Hypothesis

One probable explanation for the variable findings described above is that T and C interact to regulate dominance, such that neither hormone alone predicts competitive behavior. The "dual-hormone hypothesis" instead suggests that the positive relationship between T and dominance pertains only to individuals with low levels of C, with C blocking the effect of T on dominance (Mehta and Josephs 2010). Thus, T should only increase dominance behavior and encourage higher status when C is low. There has been significant empirical support for the interaction between C and T in both men and women with respect to leadership, social status, and risk-taking in both athletic competitions and laboratory paradigms (Casto and Edwards 2016). Although there have been a few studies in nonhuman animals of the competition dynamics posited by the dual-hormone hypothesis, it is evident that T and C levels vary between dominants and subordinates according to each species' social system, reproductive strategy, and the allostatic load distribution within the dominance hierarchy.

Conclusion

Research has shown that dominant and competitive behavior is associated with changes in both T and C. In mammals, T positively correlates with dominance and with aggressive behavior, whereas C and its relationship to dominance vary across and within species. The challenge hypothesis, one of several put forward to explain hormone-behavior relationships, suggests that social and environmental factors affect changes in T concentration. The biosocial model of status expands the challenge hypothesis to predict that T concentrations should increase in winners and decrease in losers in human competitions, allowing individuals to quickly adjust to changes in their social status. In competitive situations, C has also been shown to moderate the psychological effects of T, and more recent research has suggested that the relationship between T and dominance is only true for individuals with low levels of C. This dual-hormone hypothesis may explain individual differences in dominance behavior that remain unexplained by single-hormone studies of dominance.

From an evolutionary standpoint, these divergent hormonal responses may allow for rapid adjustment in social behavior relative to changes

in the social environment. In winners, the increase in T may promote the competitive, aggressive behavior necessary to defend their status, and the decreased T levels in losers may promote submissive behaviors that permit avoidance of physical injury and prevent further loss of status. Overall, the short-term changes in hormone concentrations modulate social behavior and dominance and likely have far-reaching fitness implications for individuals. This idea remains relevant as researchers work to develop a deeper understanding of the variety of hormonal mechanisms that underlie dominance and aggression in human and animal societies.

Cross-References

- ▶ Bidirectional Relationship Between Serotonin and Dominance
- ▶ Biosociology of Dominance and Deference
- ▶ Dominance and Health
- ▶ Dominance and Status in Nonhumans
- ▶ Dominance and Testosterone
- ▶ Dominance Hierarchies
- ▶ Dominance Hierarchies Shift
- ▶ Dominance in Humans
- ▶ Emergence of Dominance Hierarchy
- ▶ Evolutionary Theories of Status, Dominance, and Prestige
- ▶ Female Dominance Hierarchies
- ▶ Function of Dominance
- ▶ Indicators and Correlates of Status and Dominance
- ▶ Male Dominance Hierarchies
- ▶ Marks of Status
- ▶ Men, Women, and Status-Striving
- ▶ Primate Dominance Hierarchies
- ▶ Serotonin, Testosterone, and Dominance
- ▶ Social Hierarchies
- ▶ Status and Dominance Hierarchies
- ▶ Status Competition
- ▶ Stress and Cortisol

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