

# Importance of Considering Testosterone–Cortisol Interactions in Predicting Human Aggression and Dominance

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A novel “field” study recently published in *Aggressive Behavior* found that individual differences in baseline testosterone concentrations were positively correlated with endorsement of political aggression and that baseline cortisol concentrations were negatively correlated with self-reported aggression among Palestinian boys living in Gaza. Here, we discuss recent evidence indicating that testosterone and cortisol interact to predict competitive, aggressive, and dominant behaviors and urge researchers collecting both hormones to perform and report analyses that formally test for such interaction effects. *Aggr. Behav.* 37:1–3, 2011. © 2011 Wiley-Liss, Inc.

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Dear Editor,

We read with interest a recent article published in *Aggressive Behavior* entitled “Support for religio-political aggression among teenaged boys in Gaza: Part II: Neuroendocrinological findings.” Here, the authors collected saliva samples for the assessment of testosterone and cortisol from adolescent boys and examined whether variation in these hormones would be associated with self-report aggression and one’s endorsement of political aggression. Results indicated that testosterone was positively correlated with support for religio-political aggression (RPA), but not with self-reported aggression. Further, baseline cortisol was negatively correlated with self-reported aggression and anger, but not with RPA. Two major strengths of the article were that: (1) testosterone and cortisol were measured repeatedly to obtain a reliable measure of “baseline” hormone concentrations and (2) this study examined hormone–behavior associations in a “field” setting increasing the study’s ecological validity and real world applications.

The ease with which testosterone and cortisol can be assessed through saliva has led to a significant rise in research examining hormonal correlates of

human behavior. Moreover, many researchers have begun to assess both testosterone and cortisol concentrations in the same study. This is particularly important given the known functional interactions among the hypothalamic–pituitary–adrenal (HPA) and hypothalamic–pituitary–gonadal (HPG) axes, endocrine systems regulating the release of cortisol and testosterone, respectively [Viau, 2002]. Such studies have uncovered fascinating testosterone–cortisol interactions in predicting human social behavior [Dabbs et al., 1991; Mehta and Josephs, 2010; Popma et al., 2007; but see Scerbo and Kolko, 1994]. In all these studies, baseline testosterone concentrations were positively correlated with aggressive, competitive, and dominant behavior, but only among individuals with low baseline

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cortisol concentrations. Among individuals with high baseline cortisol, testosterone was either unrelated to behavior [e.g., overt aggressive behavior, Popma et al., 2007] or was negatively correlated with behavior [competitive behavior after defeat, Study 2, Mehta and Josephs, 2010]. These studies provide initial support for the idea that testosterone and cortisol interact to modulate human aggression and dominance. Mehta and Josephs [2010] speculate based on neurobiological evidence that these dual-hormone interactions may occur through the inhibitory effects of cortisol on the pathway between testosterone and behavior. When HPA output is low (i.e., low cortisol), the pathway between testosterone and behavior functions efficiently; hence, higher testosterone should have a strong effect on aggression and dominance. However, when HPA output is high (i.e., high cortisol), the pathway between testosterone and behavior is inhibited [see Mehta and Josephs, 2010 for evidence in support of this mechanism]. This putative mechanism fits with a broader evolutionary approach to understanding the roles of the stress (HPA) and reproductive (HPG) axes in modulating complex social behavior. Specifically, high levels of stress in the environment should block the effect of testosterone on reproductively relevant behaviors such as competition over mates, because such behaviors are metabolically costly and potentially dangerous. Only when levels of stress in the environment are low should behaviors relevant to reproduction such as aggression, dominance, and mate-seeking be expressed (behaviors commonly associated with high testosterone levels).

Victoroff et al. [2010] tested for simple bivariate (zero-order) correlations between hormone and outcome variables. However, it would have also been useful to perform multiple regression analyses with testosterone and cortisol simultaneously entered as predictors of the outcome variables (RPA and self-report aggression).<sup>1</sup> Results from such analyses would inform the reader of whether testosterone and/or cortisol explained a unique proportion of variability in the outcome variables. Going beyond main effects, and in accordance with previous studies [e.g., Dabbs et al., 1991; Mehta and Josephs, 2010; Popma et al., 2007], the authors could have entered the testosterone–cortisol interaction term to assess whether it accounted

additional variance above and beyond that explained by the main effects. We have discovered that Victoroff et al. [2010] tested this model and found no evidence for testosterone–cortisol interactions [Victoroff, personal communication]. As very few studies have examined testosterone–cortisol interactions, we strongly urge researchers to test for interactions and report both significant and nonsignificant findings. Reporting nonsignificant findings will enable researchers conducting work in this area to gain a more complete understanding of when testosterone–cortisol interactions emerge and when they do not. Given the small sample size ( $N = 41$  participants with both testosterone and cortisol measures) in the Victoroff et al. [2010] study, it is not surprising that the interaction did not emerge as a statistically significant predictor of RPA and/or self-report aggression. Indeed, previous studies that have found significant interactions have had sample sizes ranging from 57 to 103 [mean = 91.75,  $SD = 24.43$ ; Dabbs et al., 1991; Mehta and Josephs, 2010; Popma et al., 2007]. Thus, to detect small to medium effect sizes, future studies should be conducted with relatively large samples (e.g.  $N = 100$ – $150$  participants) to have sufficient statistical power to detect testosterone–cortisol interactions.

Given the functional interactions between the HPA and HPG axes [Viau, 2002] and recent evidence indicating that the relationship between testosterone and human competitive, aggressive and dominant behavior depends on cortisol, we urge researchers to carefully consider potential interactions among these neuroendocrine systems. Meta-analyses suggest that the direct relationship between testosterone and human aggression is weak and inconsistent [Archer et al., 2005]. We argue that inconsistencies may arise because most human behavioral endocrinology studies to date test for independent effects of testosterone and cortisol on behavior but fail to formally test for potential interactions between these hormones. We suspect that future research that considers interactions between the HPG and HPA axes will lead to more reliable prediction of complex social behavior and will engender significant advances in the growing field of social neuroendocrinology in the years to come.

## REFERENCES

- Archer J, Graham-Kevan N, Davies M. 2005. Testosterone and aggression: A re-analysis of Book, Starzyk, and Quinsey's (2001) study. *Aggr Viol Behav* 10:241–261.

<sup>1</sup>Of note, given the moderate positive correlation between testosterone and cortisol [ $r$ 's from .28 to .35 e.g., Mehta and Josephs, 2010; Popma et al., 2007; Victoroff et al., 2011], researchers should mean-center variables prior to analyses to avoid problems with multicollinearity.

- Dabbs Jr J, Jurkovic G, Frady R. 1991. Salivary testosterone and cortisol among late adolescent male offenders. *J Abnorm Child Psychol* 19:469–478.
- Mehta PH, Josephs RA. 2010. Testosterone and cortisol jointly regulate dominance: Evidence for a dual-hormone hypothesis. *Horm Behav* 58:898–906.
- Popma A, Vermeiren R, Geluk CA, Rinne T, van den Brink W, Knol DL, Jansen LMC, van Engeland H, Doreleijers TAH. 2007. Cortisol moderates the relationship between testosterone and aggression in delinquent male adolescents. *Biol Psychiatry* 61:405–411.
- Scerbo AS, Kolko DJ. 1994. Salivary testosterone and cortisol in disruptive children: Relationship to aggressive, hyperactive, and internalizing behaviors. *J Am Acad Child Adolesc Psychiatry* 33:1174–1184.
- Viau V. 2002. Functional cross-talk between the hypothalamic-pituitary-gonadal and -adrenal axes. *J Neuroendocrinol* 14:506–513.
- Victoroff J, Quota S, Adelman JR, Celinska B, Stern N, Wilcox R, Sapolsky RM. 2011. Support for religio-political aggression among teenaged boys in Gaza: Part II: Neuroendocrinological findings. *Aggr Behav* 35:1–12.