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Testosterone and social evaluative stress: The moderating role of basal cortisol

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Summary Research has suggested that stressful situations lead to a decrease in testosterone, whereas concern with one's social status increases testosterone. However, results from studies examining testosterone reactivity in stressful situations that involve evaluation by others (hence status concerns) are inconsistent. Furthermore, there is a lack of research examining individual differences in testosterone responses in such situations. In this study 85 male participants underwent the Trier Social Stress Test (TSST, which includes performing speech and arithmetic tasks in front of two critical evaluators) and practiced solving puzzles. Testosterone and cortisol levels were assessed from saliva. Across participants, testosterone increased from baseline to peak levels following the stressor tasks. Importantly, the increase in testosterone was larger for participants with lower basal cortisol. Hence, lower basal cortisol (which is known to be associated with low social fearfulness) may help one to mobilize a larger testosterone response in situations that involve social-evaluative stress. Given the hypothesized adaptive role of a larger testosterone response in social competition situations, the results suggest that there may be long-term benefits in learning to lower one's social fearfulness in situations involving potential for negative evaluation by others.

Over 70 years ago, Selye (1936) proposed that when confronted with a stressor, the body prepares physiologically to deal with the stressor. It has been hypothesized that during a stressful situation, physiological mechanisms that are not urgently needed to deal with the stressor are temporarily suppressed (Chichinadze and Chichinadze, 2008). The reproductive system is one example of a physiological system that should theoretically be suppressed in a stressful situation. Indeed, many animal and some human studies have suggested that amidst stressful situations (such as physical stress) the sex hormone testosterone decreases. However, some studies have found the opposite: an increase in testosterone during stressful situations (see review by Chichinadze and Chichinadze, 2008). A possible reason for this inconsistency may be the nature of the stressful event. Concerns about one's social status in a group (i.e.,

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dominance concerns) result in an increase in testosterone (see review by Eisenegger et al., 2011). We hypothesized that the degree to which a stressful situation is perceived as a dominance interaction is the critical factor that determines whether testosterone increases or decreases.

Research has suggested that increases in testosterone levels may be associated with benefits during social challenges, such as increased self-efficacy, persistence, focusing on one's goals, enhanced learning, reinforcing successful competition behavior, adapting better strategies to improve social status, and better performance (Boksem et al., 2013; Henry, 1982; Mazur and Booth, 1998; Salvador et al., 2003; Schultheiss and Rohde, 2002; Turan et al., 2014). Increased testosterone levels are also associated with increased metabolism, synaptic plasticity, as well as spatial and verbal memory (Cherrier et al., 2001; Schulz and Korz, 2010; Tsai and Sapolsky, 1996). Furthermore, experimental research suggests that administering testosterone increases competitiveness and dominance-related behaviors, and reinforces successful behaviors in animals as well as in people (Carre and Putnam, 2010; Enter et al., 2014; Frye et al., 2002; Terburg et al., 2012). According to the ''challenge hypothesis,'' testosterone assists an individual to prepare for challenges such as an opportunity to show or gain dominance (Archer, 2006; Mazur and Booth, 1998; Wingfeld et al., 1990). Thus, an increase in testosterone may be part of an adaptive strategy when facing social challenges (Boksem et al., 2013).

It should be noted that hormonal responses to external stimuli are not immediate. The brain, on the other hand, responds to external stimuli almost immediately. Thus, the proposed benefits of a testosterone response in evaluative situations can only be observed in later stages of facing a challenge, and it may be more appropriate to conceptualize a testosterone response as part of a larger stress-responsive system. Many studies have also reported a substantial testosterone response in anticipation of a challenge or a stressor, and this anticipatory response is hypothesized to prepare the individual for the upcoming challenge (reviewed in Salvador, 2005). Thus, we can we expect a testosterone response to affect behavior when facing prolonged stressors, or when the onset of the stressor can be anticipated in advance.

An experimental paradigm that evokes evaluative stress is the Trier Social Stress Test (TSST; Kirschbaum et al., 1993). In the TSST, participants prepare and deliver a speech as well as perform difficult arithmetic tasks in front of evaluators, who are deliberately quite critical. Thus, the TSST combines stress and social evaluation, and therefore provides a good medium to examine changes in testosterone in situations involving social-evaluative stress. Few studies have examined the effects of social-evaluative stress on testosterone, and these have yielded inconsistent results. Some studies found a significant increase in testosterone (Lennartsson et al., 2012), whereas others found no change (Gerra et al., 2000; Heinz et al., 2003; Schoofs and Wolf, 2011). We argue that two factors may be important in resolving these inconsistencies in previous evaluative stress research: (a) individual psychological and physiological differences that affect a person's response to the situation, and (b) methodological differences among studies.

In social evaluative situations, individuals who have intense worries about being evaluated negatively might perceive the situation more as a stressor than a competition, and therefore show a decrease in testosterone. Such a cognitive appraisal, which is made at a neural level, could then alter endocrine responses, e.g., by changing testosterone levels. Chronic stress related to social evaluation may be another important individual difference that affects the testosterone response to a social evaluative stressor (Chichinadze and Chichinadze, 2008). Interestingly, the only TSST study that found a significant increase in testosterone (Lennartsson et al., 2012) only included participants who reported very little chronic stress.

Cortisol is a glucocorticoid hormone released in response to stressors. High basal levels are implicated in chronic social-evaluative and social hierarchy stress, and in social avoidance (Mehta and Josephs, 2010). Thus, individuals with high basal cortisol levels might perceive a social evaluative situation as threatening to their social status rather than as a dominance challenge, and therefore may show a blunted testosterone response. Cortisol might also have direct biological effects on testosterone reactivity, since the hypothalamic–pituitary–adrenal (HPA) axis and the hypothalamic–pituitary–gonadal (HPG) axis that are responsible for the secretion of cortisol and testosterone, respectively, are known to interact with each other (Lennartsson et al., 2012; Schoofs and Wolf, 2011). Furthermore, previous research suggests that testosterone and cortisol can have joint effects on outcomes. For example, testosterone may be associated with aggression only for individuals with low cortisol (Dabbs et al., 1991; Mehta and Josephs, 2010; Popma et al., 2007). Unlike the present study, these studies used testosterone as the independent variable. Nevertheless, their findings suggest the possibility that cortisol might affect testosterone responses in social evaluative situations. Therefore, in the present study we examined basal cortisol as a possible individual difference variable predicting testosterone responses in situations involving evaluative stress.

In regard to methodological issues, most studies examining testosterone in situations involving social-evaluative stress have had small samples consisting of both men and women. Since gender can moderate the testosterone response, these studies had to analyze gender groups separately, effectively decreasing sample size. Given that there are large inter-individual differences in testosterone reactivity (Lennartsson et al., 2012), at least a moderately large sample of each gender is needed. Furthermore, some studies were conducted in the morning and some in the afternoon, which may have affected results, given testosterone's strong diurnal rhythm. Another important methodological issue has been the timing of testosterone measurements with respect to stressor onset. For example, in their TSST study, Schoofs and Wolf (2011) took a final saliva sample 25 min after the onset of stress, and did not find a significant change in testosterone. They acknowledged that having a later measure of testosterone may have yielded a significant change in testosterone. To this, Lennartsson et al. (2012), who took a final sample 50 min after stressor onset did find a significant increase between pre-stress and peak levels of testosterone (whether the peak level occurred immediately post-stress or much later).