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Performance during competition and competition outcome in relation to testosterone and cortisol among women

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ABSTRACT

A contribution to a special issue on Hormones and Human Competition.
This study investigated the relation between competition, testosterone (T), and cortisol (C) in women. One hundred and twenty female participants competed against a male confederate in a computerized laboratory task. The task was preprogrammed so that half the women won and half of the women lost the competition. T and C concentrations were measured in saliva samples collected at four time points before and after the competition. Accuracy and reaction time during the competition were recorded. T and C increased directly after the competition, though not significantly for C, and then decreased over time regardless of the competition outcome. Regression analyses demonstrated that baseline T was significantly and positively associated with competition accuracy, though only in individuals who were low in C. Individuals who were high in C showed no relation between T and accuracy. This relation was further qualified by competition outcome. Losers of the competition showed a significant positive relation between baseline T levels and competition accuracy, though only if they were low in C. No relation was found between T and accuracy in losers who were high in C. Winners of the competition showed no relation between T and accuracy, regardless of whether C levels were high or low. These results are in line with the dual-hormone hypothesis, whereby the effects of T on status-seeking behaviors are dependent on C levels for individuals whose status is threatened.

1. Introduction

Competitive interactions afford individuals the opportunity to gain or maintain high social status, which allows access to important resources related to survival and reproduction in a social species (Buss, 1988; Stockley and Bro-Jørgensen, 2011; West-Eberhard, 1979). Two hormones that have been strongly implicated in competition and behaviors related to gaining and maintaining social status are testosterone (T) and cortisol (C) (Bateup et al., 2002; Booth et al., 1989; Costa and Salvador, 2012; Edwards et al., 2006; Edwards and Kurlander, 2010; Jiménez et al., 2012; Kivlighan et al., 2005; Mazur and Lamb, 1980; Mazur et al., 1992; Mazur et al., 1997; Mehta and Josephs, 2006; Mehta et al., 2009; Mehta et al., 2015; Oliveira et al., 2013; Schultheiss et al., 2005; Stanton and Schultheiss, 2007; Suay et al., 1999; van Anders and Watson, 2007; van der Meij et al., 2010).

Early studies examining the relation between status and T in humans found a link between baseline levels of T, assertiveness and aggressiveness, and other status-seeking behaviors (Cashdan, 1995; Dabbs and Dabbs, 2001; Grant and France, 2001; Mehta et al., 2008; Mehta et al., 2009). Individuals with higher baseline levels of T were rated by their peers to be more socially dominant (Cashdan, 1995), were found to be more assertive (Grant and France, 2001), performed better in competitions where they competed alone as compared to group competitions (Mehta et al., 2009), and also showed a greater inclination to compete again following the competition if they won (Mehta et al., 2008). Although individual differences in baseline T levels may be relatively stable over time and be influenced by genetic characteristics, prenatal hormonal exposure, or stable environmental conditions (Kempenaers et al., 2008), T levels are also known to fluctuate predictably in relation to changes in reproductive condition or the social environment (Wingfield et al., 1990). According to the Biosocial Model of Status (Mazur, 1985), T responses to social challenges should differ among individuals, depending on their previous experiences and dominance position (Carre and Olmstead, 2015; Casto and Edwards, 2016; Hamilton et al., 2015). One assertion of the Biosocial Model of Status is that individuals who have recently won a competition are more likely

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to experience a rapid rise in T, whereas individuals who have recently lost a competition are more likely experience a rapid decline in T. Numerous studies have supported this prediction, although these effects are often weak and have been explored more extensively in men than in women (Booth et al., 1989; Costa and Salvador, 2012; Geniole et al., 2016; Gladue et al., 1989; Jiménez et al., 2012; Mazur and Booth, 1998; Mazur and Lamb, 1980; Mazur et al., 1992; Oliveira et al., 2009; Serrano et al., 2000; van Anders and Watson, 2007).

A second assertion of the Biosocial Model of Status is that higher T, both baseline levels and fluctuations in response to the environment, is associated with greater motivation to compete to gain or maintain social status (e.g., Booth et al., 1989; Costa and Salvador, 2012; Hamilton et al., 2015; Suay et al., 1999), however there is no strong and unequivocal support for this assumption. Some previous studies of competition have used mood as a proxy for motivation (Booth et al., 1989; Mazur and Lamb, 1980), while others have relied on self-report measures of motivation (Costa and Salvador, 2012; Suay et al., 1999). Performance throughout the actual competition may reflect how engaged an individual is and the extent to which he or she wants to win. However, the direct impact of baseline T or fluctuations in T on competition performance itself has been difficult to quantify. In field studies of sports activities, it can be difficult to objectively track an individual's performance throughout a competition, so in some cases subjective measures have been used (Serrano et al., 2000; Trumble et al., 2012). Whenever objective measures of performance have been related to T levels (González-Bono et al., 1999; Kivlighan et al., 2005; Trumble et al., 2012), hormonal fluctuations were likely confounded by the physical nature of the competition (Kraemer and Ratamess, 2005; Webb et al., 1984). Laboratory studies that have quantitatively tracked performance during competition have found mixed results, with T both positively (Costa and Salvador, 2012; Mehta et al., 2009; Schultheiss et al., 2005) and negatively (Kivlighan et al., 2005; Mehta et al., 2009; van Anders and Watson, 2007) associated with performance.

Similar to T, C fluctuates in response to challenging or threatening situations (Del Giudice et al., 2011; Dickerson and Kemeny, 2004; Sapolsky, 2004). C prepares an individual to appropriately respond to a perceived challenge or threat (Del Giudice et al., 2011), and it therefore has been studied in relation to status seeking behaviors and competition (Salvador, 2005; Salvador and Costa, 2009). The studies that have examined the relation between C and competition outcome have produced mixed results, with some studies showing increases in C across both winners and losers, increases in C in either the winners or the losers, or no significant changes in C in response to competition (Bateup et al., 2002; Booth et al., 1989; Costa and Salvador, 2012; Edwards and Kurlander, 2010; Edwards et al., 2006; Elias, 1981; Filaire et al., 2001; Jiménez et al., 2012; Kivlighan et al., 2005; Mazur et al., 1997; Oliveira et al., 2009).

It has been suggested that the relation between T and status seeking behaviors may be best qualified through its interaction with C (Mehta and Josephs, 2010). This dual-hormone hypothesis posits that T is associated with status-seeking or dominant behaviors only when C is low, such that individuals who are high in T and low in C demonstrate greater dominant behaviors than those individuals who are high in T and high in C. When C is high, T is unrelated to status-seeking or dominant behaviors (Mehta and Josephs, 2010; Mehta and Prasad, 2015). In other words, status-seeking or dominant behaviors are jointly regulated by T and C. This relation has been further qualified by environmental context. Support for the dual-hormone hypothesis has been found in men in a competitive setting, but only in those individuals who have recently lost a competition (Mehta and Josephs, 2010). Men who recently lost a competition were more likely to choose to compete again in the same competition if their T levels were high and C levels were low. Men who recently won a competition did not show this relation between their desire to compete again and their T and C levels. In other words, men high in T and low in C chose to compete again only after they lost status through losing the competition (Mehta and Josephs, 2010).

Despite the growing number of studies examining the relation between competition, T, and C, many aspects of the relation between competition, T, and C remain unexplored. First, given the paucity of competition studies involving women (in terms of both women competing against other women and women competing against men), it is not clear whether the hormonal responses to competition observed in men also reliably occur in women. Second, to our knowledge, all studies to date have explored hormonal fluctuations during same-sex competitive interactions. It remains unclear whether hormonal changes observed in same-sex competitions also occur when competing against the opposite sex. Third, the relation between hormones and performance during a competition remains unclear, particularly whether T, C, or their interaction may be associated with performance in the competition and whether this may be qualified by the competition outcome (i.e. winning or losing).

This study was designed to address some of these gaps in our knowledge of the relation between competition, T, and C. Our first goal was to investigate the effects of winning or losing on hormone levels among women who compete against men. We hypothesized that women who won the competition against men would demonstrate an increase in their T levels, whereas women who lost the competition would experience a decline in T. A second goal of this study was to explore in detail the possible relation between hormone levels (baseline and fluctuations), competition outcome, and performance during the competition. We hypothesized that winners would demonstrate overall higher accuracy in the competition than losers due to increased motivation to secure a win after positive feedback on initial rounds of the competition (Vallerand, 1983; van Dijk and Kluger, 2011). Additionally, we hypothesized that women who had higher levels of baseline T or greater increases in T across the competition would demonstrate higher accuracy as they attempted to win the competition. In other words, we hypothesized that increased T levels would be associated with better accuracy in the competition, as T may affect motivation and effort to do well in the competition in order to maintain or gain status against the competitor. In line with the dual-hormone hypothesis, we hypothesized that C would affect competition performance through its interaction with T, such that individuals high in T and low in C would perform the best.

2. Material and methods

2.1. Participants

One hundred and twenty women (age: $M = 21.75$, $SD = 2.96$) were recruited online and through flyers. Women were eligible to participate if they answered >5, the midpoint, on two 9-point Likert scale questions ("I am good at math", "It is important to me that I am good at math"). This eligibility requirement was used as it pertained to a second task that was completed following the competition. Participants were reimbursed 1.5 course credits or $15.00 for study participation. Those participants assigned to the winning condition received an additional $5.00 for participation.

2.2. Study design

Participants engaged in a competition against a male confederate who they were led to believe was another participant. Participants were randomly assigned to a winning or losing condition for the competition task. The asterisks in the competitive paradigm (described below) were presented in a random order in all blocks. Accuracy and reaction time in the competitive paradigm were compared across winners and losers. Saliva samples were collected at various time points throughout the tasks to assess hormone levels via ELISA (see below). All

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