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Brief communication

Baseline cortisol moderates testosterone reactivity to women's intercollegiate athletic competition

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HIGHLIGHTS

- Women athletes gave saliva samples before and after an athletic competition.
- Athletic competition increased salivary cortisol and testosterone.
- High cortisol women had a reduced testosterone response to competition.
- Cortisol appears to moderate testosterone reactivity to athletic competition.

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ABSTRACT

Recent research suggests that cortisol (C) level moderates testosterone (T) reactivity to the Trier Social Stress Test (TSST) in men. The extent to which C moderates T reactivity in other circumstances and in women is not known. In this retrospective study, before- and after-competition salivary levels of C and T from 97 intercollegiate women athletes competing in one of four different sports (soccer, volleyball, softball, tennis) were used to evaluate the influence of before-competition C level on T reactivity in women's athletic competition. Athletic competition was associated with a substantial increase in salivary levels of C and T in the vast majority of athletes. Before-competition level of C significantly moderated testosterone reactivity to athletic competition — women with relatively low levels of C showed larger increases in T to competition than women with higher levels of C. Clearly, the moderating effect of C on T reactivity is not limited to laboratory settings intended to increase social stress, but is also seen in (as we show here) the context of athletic competition.

1. Introduction

The Trier Social Stress Test (TSST) [1] is a commonly used standardized protocol for reliably inducing "social" stress in human participants in a laboratory setting. Following this protocol, participants prepare and then deliver a speech to a critical and sometimes questioning audience of one or more evaluators. After that, they are asked to do some mental arithmetic for the same audience; mistakes noted by one of the evaluators require the participant to start again from the beginning. The TSST increases levels of a number of physiological substances believed to be markers for psychological stress, including the adrenocortical hormone cortisol (C). The increase in serum levels of C is apparent immediately after the end of the stressor and is followed by a corresponding increase in salivary C 10 min later. These increases are seen in more than 70% of participants [1,2].

Testosterone (T) is a steroid hormone related to dominance motivation and social status in men [3–5] (for reviews). In their comprehensive 2008 review, Chichinadze and Chichinadze[6] noted that although many studies document that chronic stress can inhibit testicular function and decrease T level, acutely experienced stress can actually increase T level in blood. Lennartsson et al. [7] were apparently the first to report that the TSST could increase serum levels of T in men and women. Bedgood et al. [8] showed that the TSST could increase salivary levels of T in men and, in addition, that this increase was moderated by basal (before-testing) levels of C. That is, the lower a participant's basal level of cortisol, the larger the testosterone response to the TSST. Transient increases in T are seen in a variety of other social interactions in which status is contested e.g., [3,9,10], and may function to promote the motivation for status-seeking/competitive behaviors in some settings [11]. If higher baseline levels of C decrease T response to stress, this could negatively impact testosterone-driven achievement motivation in stressfully challenging situations, particularly ones that are socially contextualized. The extent to which C moderates T reactivity in circumstances other than the TSST and in women is not known. Stress can take many forms and it is of obvious importance to determine the extent to which C can moderate T reactivity in other more "natural" circumstances.

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For more than a decade, one of us (DE) has studied the effect of intercollegiate athletic competition on salivary levels of C and T in men and, more frequently, women. Most men soccer players and cross country runners show a substantial increase in salivary C and T in association with intercollegiate competition [12,13]. The same is true for women soccer players [12], cross country runners [13], and volleyball and tennis players [14]. For women softball players, the competition-related increase in C is not as consistently evident as for other sports, but competition is associated with a substantial elevation in salivary T [15]. For all the sports we have studied, elevations in C and T were specific to individuals who played and were not seen in teammates who did not compete. These results are in accordance with other studies of men and women athletes documenting an increase in C and T associated with athletic competition e.g., [16–19].

For this article, we combined the results of nine different studies with intercollegiate women athletes to give a sample size of 97 women for whom we have before-competition (baseline) and after-competition values for salivary C and T. Analysis of these data gives new information about the extent to which the T response to athletic competition in women is moderated by C.

2. Methods

2.1. Participants

Participants were the consenting members of the Emory University (Atlanta, GA) women's 2002, 2005, and 2008 women's volleyball teams [14,15], the 2004 softball team [15], the 2009 tennis team [14], the 2010 and 2011 cross country teams [13], and the 1999 and 2013 soccer teams [12] (and K. Casto and D. Edwards, unpublished). All of the studies were approved by Emory's Institutional Review Board. Virtually all members of each of the teams studied gave informed consent and went on to participate in the research. Consent procedures, which included collecting information about oral contraceptive (OC) use, have been described elsewhere e.g., [13,14]. Participants were included for data analysis only if we had before- and after-competition saliva samples for the selected competition and they had actually competed in the contest — a single cross country race (N = 26), a doubles tennis match (N = 6), a best-of-5-sets volleyball match (N = 28), or a softball (N = 9) or soccer game (N = 28). Some volleyball players and runners gave samples during two different years. So that these individuals would only make a single contribution to the data pool, we arbitrarily used only their values for the competition occurring during their more senior year. The sample sizes above do not include one volleyball player who left the match because of a serious injury and one cross country runner who gave an ambiguous response to the query about contraceptive use.

2.2. Saliva samples and hormone assay

For all of the studies drawn upon for this report, saliva was collected for coach-selected competitions following our usual protocol [13,14]. Competitions began as early as 10 AM (cross country) and as late as 7 PM (volleyball). On the day of competition, participants gave their first sample immediately prior to warm-up, which began approximately 1 h before the start of play. Participants gave another sample immediately after the end of the competition. Participants were provided with a piece of sugar-free gum (Trident®, original flavor) to stimulate saliva production and a 20 ml polypropylene vial which they were asked to fill to a 5 ml line marked on the side. Participants chewed for a timed 2 minute period before starting to fill the vial. Including the pre-delivery chewing period, collection of a single saliva sample typically took 4–7 min. This procedure was repeated immediately after the end of the competition, so that after-competition samples were received within 15 min after the completion of the race (cross country), the game (soccer and softball), best-of-five-sets match (volleyball), or doubles-competition (tennis). The cross country races were for an away-from-home meet and were completed in less than 30 min. All other competitions were played at home and were between 1 and 2 h in duration. Start times for the various competitions are shown in Table 1.

Although the use of chewing gum to stimulate salivation and speed collection of saliva samples is common, this practice has been recently questioned in a report [20] that chewing gum may distort salivary T levels relative to unstimulated samples. In the present study, all participants chewed Trident® original flavor gum. Provided individuals chew for more than 1 min before they begin to deliver the sample, this particular gum does not appear to affect salivary T level relative to what is assayed from unstimulated samples [21,22].

Samples were frozen and later sent to the Biomarkers Core Laboratory of the Yerkes Primate Center in Atlanta, Georgia for hormone assay. Assay procedures have been described elsewhere [13,14]. The mean inter-assay coefficients for the various assays of C and T were 5.2% and 12.0%, respectively. The mean intra-assay coefficients of variation for C and T were 8.0% and 5.6%, respectively.

2.3. Statistical analyses

Following Bedgood et al. [8], hormone values were log-transformed to achieve normal distributions, and T reactivity and C reactivity were calculated by subtracting before-competition values from after-competition values. To adjust for team-based differences in before-competition hormone levels, before-competition untransformed T and C values were standardized (z-score) within each team/competition for purposes of regression analysis. A t-test for independent groups was used to assess differences in z-transformed baseline T and C levels for oral contraceptive (OC) users and non-users. A multiple regression analysis was conducted to assess the effect of OC use, before-competition C level, and their interaction on T reactivity to athletic competition. Prompted by reports that T can moderate C reactivity in certain competitive settings [23,24], we also assessed the effect of OC use, before-competition T level, and their interaction on C reactivity to competition. The after-competition C value for one athlete was greater than 3 standard deviations higher than the mean for the group — this value was excluded from all analyses using after-competition C levels. A Pearson correlation coefficient was calculated to illustrate the relationship between T reactivity and C reactivity to competition.

3. Results and discussion

In accordance with earlier reports (some with these same participants), team athletic competition was associated with an increase in salivary levels of C and T in over 80% of the women athletes studied, with increases averaging 126% and 58%, respectively. C and T appear to rise in parallel in response to athletic competition e.g., [12], and C reactivity and T reactivity for women in this study were significantly correlated ($r(94) = 0.34$, $p < .001$). C and T reactions to athletic competition may be related through their shared connection to the psychological experience of athletic competition. In the athletic contests included in this report, competition-related increases in T are seen regardless of match or race outcome (Table 1), with T increasing in competitions that were won (1999 soccer; 2002 volleyball; 2008 volleyball, one 2009 doubles tennis match), and lost (2004 softball, 2005 volleyball, two 2009 doubles tennis matches, and 2013 soccer). The effect is also seen in cross country racing, where the runner crossing the finish line first is the only “winner” and where team outcome is not decided until long after all the racers have finished the course.

Both C and T in plasma increase during non-competitive aerobic exercise in proportion to the intensity and/or duration of the workout e.g., [25–27]. Softball is a sport which, unlike all the others studied here, does not involve a sustained period of physical exertion. Although mean T reactivity was lowest for the softball players (19% increase), T