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Endogenous testosterone levels are associated with assessments of unfavourable health information

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The purpose of this study was to investigate whether participants' assessments of unfavourable health information are associated with individual differences in basal testosterone. Testosterone has previously been related to assessments of threat in social and other domains. 52 undergraduate males were tested for a minor, fictitious medical condition thioamine acetylase deficiency ('TAA deficiency') in a paradigm that was developed to examine the thoughts and behaviours of individuals who have just received unfavourable medical news. In a variation on the classic paradigm, all participants were told that they had 'TAA deficiency,' after which they rated the seriousness and prevalence of that condition as well as 19 other actual conditions. Higher testosterone levels were significantly correlated with lower estimates of both the seriousness and prevalence of TAA deficiency as well as lower median seriousness and prevalence estimates of the 19 actual conditions. Findings are discussed in light of current research in the field of behavioural endocrinology. This study provides preliminary evidence that individual differences in assessments of threatening health information may be associated with neurobiological characteristics.

Keywords: health threat; testosterone; TAA deficiency paradigm

Objective

Individuals differ widely in how they assess threatening health information. Whether that information comes in the form of public health messages or unusual changes in bodily functioning, people vary in their assessments of both the potential seriousness of a health threat and their own vulnerability to it. Understanding these variations is important because an individual's assessment of a potential health threat influences whether he or she subsequently acts in an adaptive (or maladaptive) manner. For example, individuals who perceive a low level of threat in a 'fear appeals' message are less likely to adopt the prescribed behaviour (Witte & Allen, 2000). Similarly, individuals who do not ascribe seriousness to unusual bodily changes are less likely to seek timely consultation (Cacioppo, Andersen, Turnquist, & Tassinary, 1989).

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There has been considerable interest in identifying individual characteristics that are associated with how people perceive and act on health-related threats, so that health-promoting communications might be tailored to appeal to the intended receivers (Slater, 1996). In particular, a great deal of attention has been given to threat-related emotions (i.e., anxiety, worry, and fear), not only as consequences of the assessment process, but more importantly as internal forces that motivate and shape the subsequent behavioural responses (Cameron, 2003). Studies of individual differences in health-related threat assessment have thus far been focused on self-reported personality traits and emotional dispositions. One potential avenue of investigation that has received little attention, however, is individual differences in neurobiological characteristics that may be associated with sensitivity to health-related threats. Studies of threat sensitivity in other emerging areas of research, i.e. social neuroscience (Heatherton, 2011) and neuroeconomics (Phelps, 2009), have established a clear neurobiological connection. Several especially fruitful lines of research have recently explored individual differences in the functioning of endogenous chemical messengers that govern threat-related responses in neural structures (Canli, 2009). It is the purpose of this study to determine whether individual differences in one specific chemical messenger, endogenous testosterone, are associated with assessments of health threats.

Testosterone is a neuroactive steroid hormone that exerts influence over a wide range of social behaviours related to dominance, aggression and status-seeking (Mehta & Josephs, 2011; Schultheiss et al., 2005). Further, it has been considered a biological marker of behavioural tendencies that fulfils all the criteria for a relatively stable personality trait (Sellers, Mehl, & Josephs, 2007), with testosterone levels across human males covering a remarkably wide range (Gardner, Shoback, & Greenspan, 2007). Pertinent to this investigation, testosterone also has a modulatory effect on emotional and behavioural responses to threat (van Wingen, Ossewaarde, Backstrom, Hermans, & Fernandez, 2011). In animal research, the administration of testosterone has been associated with the diminution of a broad array of 'anxiety behaviours' in response to threatening environmental stimuli (Archer, 1973; Bing et al., 1998; Boissy & Bouissou, 1994; Frye, Edinger, & Sumida, 2008). In humans, administered testosterone has been associated with decreased startle response to the threat of electrical shock (Hermans, Putman, Baas, Koppeschaar, & van Honk, 2006) as well as with a motivational shift from punishment to reward sensitivity (van Honk et al., 2004), possibly signalling the blunting effect of testosterone on sensitivity to threats. Finally, in humans greater levels of endogenous testosterone have been associated with a greater tendency to pursue reward while ignoring potential threat (Apicella et al., 2008; Stanton, Liening, & Schultheiss, 2011).

The present study

This study was designed to investigate the association between endogenous testosterone levels and assessments of mildly threatening health information in a sample of male college students. We employed a variation on the thioamine acetylase (TAA) deficiency paradigm, a procedure developed specifically to examine the thoughts and behaviours that occur when people are faced with unfavourable health information (for a review, see Ditto & Croyle, 1995). This classic paradigm involves testing participants for 'TAA', an ostensibly common enzyme that plays a role in

pancreatic functioning. Participants are told that those who are deficient in TAA are at greater risk to develop 'a complex of mild but irritating pancreatic disorders'. The test involves having participants dip a paper 'test strip' in a small amount of their saliva, and the 'diagnosis' is made depending on whether the 'test strip' turns colour. In actuality, there is no such condition as TAA deficiency. In the usual TAA deficiency study, the test is arranged so that the participants are led to believe that they either have (deficiency-present) or do not have (deficiency-absent) the condition. After learning their test results, participants assess the seriousness and prevalence of TAA deficiency. Studies have consistently found that 'deficiency-present' participants rate TAA deficiency as less serious and more prevalent compared to the 'deficiency-absent' participants (more prevalent diseases are seen as less serious than rare diseases). This pattern of findings has been interpreted as evidence that 'deficiency-present' participants engage in denial to psychologically dilute the threat of a personally relevant medical condition (Ditto & Croyle, 1995).

Because we were interested in studying individual differences in endogenous testosterone levels and their associations with sensitivity to health threats, we altered the classic TAA deficiency paradigm in two ways. First, we included only one group in which all participants were told that no colour change in the 'test strip' (actually plain construction paper) indicated TAA deficiency. Second, an additional saliva sample was collected for testosterone assays. In another variation on the classic paradigm, the saliva test was presented as a diagnostic tool currently being validated. This was done to introduce an element of ambiguity to the results so that individual differences in reaction to the test might be more clearly revealed. Because higher testosterone has been associated with a blunted sensitivity to threat, we hypothesised that higher levels of endogenous testosterone would be associated with lower ratings of the seriousness of TAA deficiency. A general blunting effect of testosterone on threat sensitivity might also predict lower estimates of the prevalence of TAA deficiency.

Design

Participants

Participants were Introductory Psychology students at the University of Texas at Austin who were recruited through a website which described study volunteer opportunities to satisfy their course research requirements. This study was described as an investigation of health and health behaviours among males. To avoid involving anyone who might be prone to experience worry in response to unwelcome medical news, potential participants completed the short version of the Health Anxiety Inventory (Salkovskis, Rimes, Warwick, & Clark, 2002) and would be excluded if they scored $\geq$1 SD above the normal mean. None of the participants scored above the cut-off criterion, so no one was excluded for having excessive health anxiety.

Seventy male students were scheduled for the laboratory study, although data from 18 of them were excluded from analysis: two for experimenter error, 10 for insufficient or contaminated saliva, three for acknowledging suspicion regarding the true purpose of the study during debriefing, and three for failing to complete the questionnaires. The 52 eligible participants ranged in age from 18 to 22 ($M = 19.4$; $SD = 0.96$), and represented the following racial/ethnic categories: 29 Caucasian, 15 Hispanic, four Asian, one African-American, one Native American and two other.

Procedure

All study procedures were approved by the IRBs at both the University of Texas and Washington University in St. Louis. After completing online recruitment measures (the screening instrument and a measure of trait anxiety), eligible participants were sent an email to schedule the laboratory portion of the study. To minimise the impact of circadian fluctuations on testosterone levels, laboratory sessions were conducted within a restricted timeframe (i.e. 12:00–5:00 pm) (Schultheiss & Stanton, 2009). At the laboratory, participants gave informed consent, provided an initial saliva sample for testosterone assays, and completed a demographic questionnaire and an investigator-prepared Health and Health Behaviours questionnaire. Next they were told about 'TAA deficiency' and asked to perform the saliva test by drooling into a small vial and then rubbing a 'test strip' in their saliva for 30 s. The experimenter then examined the 'test strip' and confirmed to the participants that their results indicated they had 'TAA deficiency'. Participants then completed a second set of questionnaires. During debriefing, participants were told the true purpose of the study, including the fact that TAA is not an actual enzyme and that the 'results' of the saliva test have no actual health implications. They were also asked whether they had suspected any deception as part of the study. Finally, debriefing information was presented to the participants in a written document, which they signed indicating that they fully understood the purpose of the study and that they could request to have their data destroyed for any reason.

Main outcome measures

Testosterone assays

Testosterone assays were conducted by the third author (SHL), using enzyme immunoassay kits from Salimetrics (College Station, PA), which feature an average recovery across known concentrations of 104.3% and a sensitivity of $<1.0\,\mathrm{pg\,mL^{-1}}$ (Salimetrics, 2011). Samples were assayed in duplicate with an average intra-assay coefficient of variation (CV) of 5.4% and inter-assay CV of 22.3% at $192.6\,\mathrm{pg\,mL^{-1}}$. There were no significant differences in mean testosterone levels between the two assays ($t(62) = 0.30$, $p = 0.77$). Testosterone levels ranged from 82.1 to $342.7\,\mathrm{pg\,mL^{-1}}$ ($Mdn = 155.1$; $M = 165.9$ and $\mathrm{SD} = 60.6$), which is comparable to published reports (Salimetrics, 2011).

Self-report measures

Both portions of the State-Trait Anxiety Inventory (STAI; Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1970) were administered. The STAI-Trait measure was administered as part of online recruitment. The STAI-State measure was administered in the laboratory immediately after participants learned of their 'diagnosis'. Internal consistency reliability was modest for both the STAI-Trait ($\alpha = 0.44$) and the STAI-State ($\alpha = 0.60$) measures in the present study.

At the same time as the STAI-State administration, participants completed an additional three-page questionnaire. The first page was labelled 'Seriousness of Chronic Conditions' and listed 20 conditions in alphabetical order, from acne and asthma to TAA deficiency and tension headaches. Participants rated the seriousness of each condition from 0 (not at all) to 100 (extremely). The second page was labelled

'Prevalence of Chronic Conditions', and listed the same 20 conditions. Here, participants estimated '*the percentage of college students you think have that condition*'. The measures of seriousness and prevalence allowed us to gather participants' estimates regarding 'TAA deficiency' as well as summary measures (medians) of the estimates of the other 19 conditions. On a scale from 1 (*'not at all'*) to 9 (*'completely'*), participants also rated both *'how confident'* and *'how concerned'* they were about their test results. Two final questions were included to gauge participants' inclination toward gathering more information about 'TAA deficiency' (Ditto & Croyle, 1995).

Statistics

Simple correlations were calculated between testosterone level and the following: seriousness and prevalence ratings of TAA deficiency; median seriousness and prevalence ratings of the 19 other conditions; confidence in, and concern about, TAA test results; and STAI-Trait and STAI-State scores. Because testosterone levels were positively skewed and because measures of disease severity and prevalence were rank-based, nonparametric tests of association (Spearman's rho) were used. All tests were two-tailed, and statistical significance was defined as $p < 0.05$.

Results

In line with our expectations, testosterone levels were associated with participants' assessments of health information. As shown in Table 1, higher levels of testosterone correlated significantly with lower estimates of both seriousness and prevalence of TAA deficiency as well as with lower median estimates of the 19 other conditions. Examination of the individual correlations between testosterone level and ratings of the seriousness and prevalence of the 19 actual conditions revealed that all but one of the 38 correlations were in the negative direction (higher testosterone related to lower ratings). These correlations ranged from near zero (seriousness of acne, asthma;

Table 1. Outcome measures and their correlations with testosterone levels.

			Testosterone level	
Measure	M (SD)	Mdn	r_s	p
Seriousness estimates				
TAA deficiency	36.4 (21.0)	37.5	−0.35	0.011
19 other conditions	50.2 (15.8)	50.0	−0.29	0.037
Prevalence estimates				
TAA deficiency	29.8 (26.9)	20.0	−0.30	0.033
19 other conditions	22.1 (16.2)	18.8	−0.31	0.024
Reactions to TAA test results				
Confidence in results	4.0 (2.1)	3.0	−0.12	0.399
Concern about results	3.2 (1.7)	3.0	−0.08	0.569
Measures of anxiety				
STAI-Trait	35.8 (9.3)	35.0	0.00	0.999
STAI-State	33.1 (10.1)	32.0	0.13	0.360

prevalence of ADD, chronic fatigue) to less than −0.3 (seriousness of Crohn's disease, epilepsy, migraine, tension headaches; prevalence of epilepsy, hypertension, psoriasis). There was no association between testosterone level and either confidence in, or concern about, TAA test results, or with either of the measures of anxiety.

Conclusion

The aim of this study was to provide a preliminary test of the hypothesis that individuals' assessments of potentially threatening health information may be associated with endogenous testosterone levels. In confirmation of this hypothesis, participants with higher testosterone levels tended to give lower seriousness estimates to their recently diagnosed 'TAA deficiency'. In itself, this could suggest that people with higher testosterone levels tend to 'deny' the seriousness of personally relevant health threats in order to protect themselves psychologically (cf. Ditto & Croyle, 1995). However, two other findings from this study suggest a different interpretation. First, higher testosterone levels were also associated with *lower* estimates of the prevalence of TAA deficiency. In the original TAA deficiency studies, the case was made that denial was indicated by *higher* prevalence estimates, the argument being that estimating higher prevalence of a personally relevant medical condition was a way of diluting its threat (Ditto & Croyle, 1995). A second finding in our study that argued against an interpretation of denial was that higher testosterone levels were associated with lower median estimates of both the seriousness and prevalence of 19 other conditions. Given these two findings, an alternative explanation is possible; that is, higher testosterone level is related to a greater tendency to downplay the dangers of medical illnesses in general, in terms of how serious and how widespread they are. Combined with the current literature on the relationships between testosterone and interpersonal behaviours, these findings may suggest that individuals with higher levels of endogenous testosterone are not only more likely to demonstrate tendencies toward dominance, aggression and risk-taking (Mehta & Josephs, 2011), but also less likely to appreciate potential dangers to their physical well being. Unexpectedly there were no associations between testosterone and either of the anxiety measures, although it has been noted that hormones tend to be associated with behavioural reactions to environmental stimuli but not necessarily with self-reported characteristics (Schultheiss & Stanton, 2009).

There are three main limitations to this study. First, because there is no objective standard for seriousness or prevalence of TAA deficiency or for seriousness of the other conditions, it was impossible to determine which levels of testosterone are associated with the most adaptive judgments. Second, because all participants were led to believe they had 'TAA deficiency', we do not know how their responses would differ from those of participants who might be told they do not have the bogus deficiency. Third, the sample was restricted to a relatively small group of college males exposed to a novel, purportedly diagnostic test, in a laboratory setting. Future studies might test whether our findings generalise to other demographic groups in more natural settings. Despite these limitations, the results of our study provide preliminary support for the original hypothesis that individuals' psychological assessments of threatening health information may be associated with neurobiological characteristics.

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