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Testosterone and temperament traits in men: Longitudinal analysis

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Summary Testosterone is the main male hormone that has been associated with various behavioral traits in humans and other animals. We investigated whether levels of total testosterone, free testosterone, and sex hormone binding globulin were associated with temperament traits in a population-based sample of Finnish men at two measurement times taken 6 years apart (n = 686 in year 2001, n = 727 in year 2007). Temperament was assessed using the Temperament and Character Inventory that consists of four temperament traits: novelty seeking, harm avoidance, reward dependence, and persistence. Higher levels of total and free testosterone were associated with higher novelty seeking (standardized B = 0.103, $p < 0.001$). This association was also observed in a longitudinal within-person analysis (B = 0.084, p = 0.008), suggesting that the association is not confounded by stable between-individual differences in other characteristics. Within-individual variation in total testosterone was associated with higher reward dependence, and higher levels of free testosterone were marginally associated with higher reward dependence. Reward dependence reflects the importance of social rewards to an individual. These results provide additional evidence for the stable and time-varying associations between testosterone and temperament in humans.

1. Introduction

Personality refers to relatively stable individual differences in behavioral, emotional and cognitive dispositions, and it is considered to be the construct that accounts for the individual consistency in behavior over time and across situations (Cloninger, 1987; Bates, 1989). The biological basis of

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personality has been investigated using various measures of genetic, neurochemical, physiological and endocrinological differences between individuals (Canli, 2008).

Testosterone is one of the most studied hormonal factors in human behavior. Previous studies have reported associations between levels of total testosterone and various personality dispositions. Testosterone has been associated with higher sensation seeking (Daitzman et al., 1978; Campbell et al., 2010) and extraversion (Alvergne et al., 2010), although not in all studies (Rosenblitt et al., 2001). Testosterone has also been associated with behaviors such as social dominance (Mazur and Booth, 1998), mating effort (Peters et al., 2008; Alvergne et al., 2009; Pollet et al., 2011), affiliative behaviors toward women (van der Meij et al., 2011), sociosexuality (Edelstein et al., 2011), competitiveness (Mehta and Josephs, 2006; Pound et al., 2009) and low risk aversion (Apicella et al., 2008).

While these findings suggest that testosterone may be associated with personality variation, there have been only a few studies of testosterone that have measured personality using a comprehensive personality model rather than single personality traits. Most of the previous studies have also been based on cross-sectional data and relatively small samples, and have assessed only total levels of testosterone but not the bioavailable free testosterone (Daitzman et al., 1978; Alvergne et al., 2010; Campbell et al., 2010). These methodological limitations hamper the conclusions on the role of testosterone in personality functioning that can be made based on current evidence.

In the present study, repeated measurements of testosterone and temperament were collected from a large sample of Finnish men to examine cross-sectional and longitudinal associations between testosterone and temperament (2001, $n = 686$ and 2007, $n = 727$ included in the final analyses). Temperament was assessed using the Temperament and Character Inventory (Cloninger, 1987; Cloninger et al., 1993), which is a widely used model of temperament used in psychobiological research. The model postulates four temperament traits reflecting automatic behavioral—emotional responses to external stimuli. Novelty seeking (NS) is related to exploratory behavior and reactivity to novel and rewarding stimuli and the neurotransmitter system related to NS is dopamine. Harm avoidance (HA) reflects behavioral inhibition and reactivity to negative and threatening stimuli and it is related to the serotonin system. Reward dependence (RD) measures affectionate behavior toward others and the maintenance of behavior in response to cues of social reward and it is hypothesized to be related to the norepinephrine system. Persistence (P) is the fourth dimension in Cloninger's model and it is expressed as industrious, hard-working, and persevering behavior. Levels of free testosterone were estimated based on total testosterone and additional measurements on sex-hormone binding globulin (SHBG) to which testosterone binds.

2. Methods and materials

2.1. Participants

The participants were from the ongoing population-based Cardiovascular Risk in Young Finns Study (CRYF) (Åkerblom et al., 1991; Raitakari et al., 2008). The original sample included 3596 randomly selected Finnish children and adolescents from six birth cohorts (aged 3, 6, 9, 12, 15 and 18 at baseline). After the baseline in 1980, the sample has been resurveyed in 7 subsequent waves: 1983, 1986, 1989, 1992, 1997, 2001, and 2007. For this study, data from men collected in 2001 and 2007 was available. All participants gave written informed consent.

In 2001 testosterone data was available for 977 and temperament data for 877 subjects and in 2007 testosterone was available for 994 and temperament for 844 subjects. Subjects included in the analyses had testosterone values over 5 nmol/l and under or equal to 40 nmol/l, and subjects missing one or more temperament or testosterone variables were not included to the analyses, thus the final sample sizes being 686 for Time 1 and 727 for Time 2.

2.2. Temperament and Character Inventory (TCI)

TCI temperament questionnaire was administered to the participants in 2001 and 2007 when the participants were 24—39 and 30—45 years old, respectively. The 40 items of novelty seeking, 35 items of harm avoidance, 24 items of reward dependence, and 8 items of persistence were rated on a 5-point Likert-type scale. Cronbach's reliability estimates for novelty seeking for the year 2001 was 0.85 and for the year 2007 it was 0.85. For harm avoidance reliabilities were 0.92 and 0.93 for reward dependence they were 0.80 and 0.82, and for persistence 0.63 and 0.68 for the years 2001 and 2007, respectively. The correlations between temperament scores across measurement times were 0.79 for novelty seeking, 0.82 for harm avoidance, 0.71 for reward dependence, and 0.66 for persistence.

In previous studies, TCI temperament traits have been shown to predict important life outcomes, including having children (Jokela et al., 2010), preclinical atherosclerosis (Hintsanen et al., 2009), depressive symptoms (Grucza et al., 2003; Jylhä and Isometsä, 2006), adolescent substance use (Wills et al., 1998), personality disorders (Battaglia et al., 1996) and long-term job strain (Hintsa et al., 2010).

2.3. Measurement of testosterone

Venous blood samples were drawn in the morning and forenoon from the right antecubital vein of recumbent subjects after a 12-h overnight fast. Blood samples were collected between 7 am and 1 pm in 2001 (80% of the samples between 7 am and 10 am). In 2007, only the beginning time of the study protocol was recorded (between 7 am and 2 pm in 2007, with 70% of the participants between 7 am and 11 am). Assessment time was not associated with testosterone levels in 2001 ($r = -0.05$, $p = 0.14$) or in 2007 ($r = 0.00$, $p = 0.91$). Serum was separated, aliquoted and stored at $-70\,^{\circ}C$ until analysis. Total testosterone was measured by Spectria Testosterone kit and SHBG by Spectria SHBG IRMA kit (Orion Diagnostica, Espoo, Finland). All analyses were carried out in the Laboratory for Population Research of the National Institute for Health and Welfare (Turku, Finland). Levels of free testosterone were calculated from free testosterone and SHBG with the use of Vermeulen's formula (FTV). FTV is most widely used in clinical practice and in the literature,

although it is known to provide overestimated values for free testosterone concentration (Vermeulen et al., 1999). However, this bias does not affect analyses of relative differences between individuals.

2.4. Statistical analyses

Associations between the repeated measurements of testosterone and temperament were tested using random-intercept multilevel regression analyses, which pooled the data from the two measurement times from two separate years into a single regression model. Four regression models were fitted (separately for each temperament trait), with temperament trait as the outcome, and age, measurement time, and smoking status (0 = non-smoker/ex-smoker, 1 = smoker) as independent variables.

In addition to the overall regression models that estimated the associations between testosterone and temperament based on between-individual and within-individual differences, we also fitted regression models assessing only the within-individual differences across the two measurement times six years apart. This analysis removes between-individual differences from the equation and estimates only whether levels of testosterone and temperament traits covary within individuals over the two measurement times. Such within-individual associations provide stronger evidence than cross-sectional associations for a causal association between testosterone and temperament. All the temperament and testosterone variables were standardized (mean = 0, SD = 1) before they were used in the analyses. In addition, all the analyses were adjusted for age: age was a covariate in all of the analyses.

3. Results

Descriptive statistics of the sample are shown in Table 1. In cross-sectional analysis, total testosterone and free testosterone (FTV) were positively associated with NS (Fig. 1), and this association was replicated in the within-individual analysis (Table 2). The association with free testosterone was somewhat stronger than with total testosterone. Higher sex hormone binding globulin (SHBG) was related to lower harm avoidance, with a similar although statistically nonsignificant association in the within-individual analysis. There was no association between testosterone and reward dependence in the overall regression combining the comparisons of between and within individuals, but in the within-individual analysis higher testosterone was associated with higher reward dependence. Also, there was a marginally significant association between free testosterone and reward dependence in the overall and within-individual analyses, but no association between reward dependence and SHBG. There were no associations with persistence.

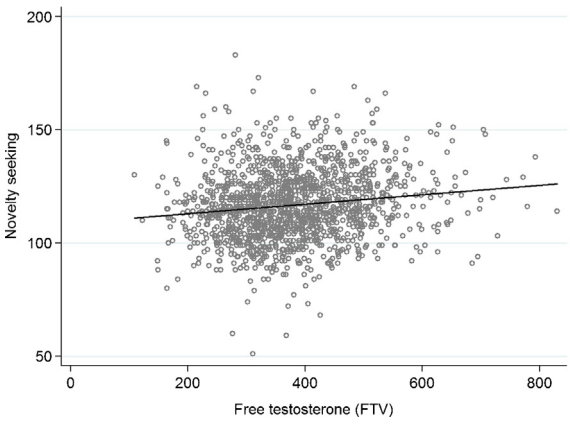

Figure 1 Novelty seeking and free testosterone.

4. Discussion

Data from a large longitudinal sample of men demonstrated that higher levels of total and free testosterone were associated with higher levels of novelty seeking. Men with free testosterone levels one standard deviation above the mean had, on average, 0.103 standard deviation higher score on novelty seeking. This association was also observed in within-person analysis, that is, across two measurement times a person's novelty seeking was higher at the measurement occasion when the person's testosterone levels were also higher. This suggests that the association is unlikely to be explained by unobserved third variables that create stable differences between individuals. The within-individual analysis thus provides supporting evidence for a causal association between time-varying levels of testosterone and novelty seeking, although it obviously cannot prove causality.

Table 1 Descriptive statistics of the sample.

Variable	2001			2007		
	Mean (Std. Dev.)	Range	*N*	Mean (Std. Dev.)	Range	*N*
Age	31.4 (5.0)	24.0–39.0	997	37.4 (5.0)	30.0–45.0	994
Novelty seeking	117.6 (15.7)	59.0–183.0	877	116.4 (15.1)	51.0–181.0	844
Harm avoidance	87.0 (17.9)	41.0–151.0	876	87.8 (17.7)	40.0–151.0	845
Reward dependence	75.1 (9.8)	33.0–102.0	881	74.0 (9.5)	36.0–107.0	845
Persistence	25.7 (4.3)	10.0–38.0	883	25.9 (4.2)	13.0–38.0	845
Testosterone (nmol/l)	18.5 (5.6)	5.9–50.0	977	16.3 (5.3)	2.3–64.8	994
Free testosterone (FTV)	409.9 (106.0)	148.3–829.8	974	352.9 (94.7)	109.0–771.9	992
Sex hormone binding globuline (SHBG) (nmol/l)	30.8 (11.9)	4.0–98.1	977	31.1 (12.0)	5.9–93.1	994

Table 2 Testosterone, free testosterone (FTV) and testosterone binding globulin (SHBG) measured from blood serum. First numbers represent results from overall regression analysis, second numbers represent within individuals regression analysis. NS = novelty seeking, HA = harm avoidance, RD = reward dependence, P = persistence.

	Standardized testosterone			Standardized FTV			SHBG		
	β	S.E.	*p*-Value	β	S.E.	*p*-Value	β	S.E.	*p*-Value
NS									
Overall regression	0.069	0.026	0.008	0.103	0.024	<0.0001	−0.0112	0.035	0.748
Within individual regression	0.075	0.039	0.051	0.084	0.031	0.008	0.030	0.065	0.650
HA									
Overall regression	−0.042	0.025	0.087	−0.007	0.022	0.765	−0.109	0.039	0.005
Within individual regression	−0.003	0.034	0.928	0.021	0.028	0.459	−0.127	0.066	0.055
RD									
Overall regression	0.030	0.028	0.278	0.050	0.026	0.054	−0.021	0.022	0.349
Within individual regression	0.100	0.045	0.028	0.071	0.037	0.056	0.025	0.048	0.612
P									
Overall regression	0.022	0.028	0.429	−0.002	0.027	0.947	0.018	0.010	0.072
Within individual regression	0.017	0.047	0.722	−0.016	0.039	0.687	0.042	0.022	0.052

High novelty seeking is closely related to sensation seeking and correlates also with measures of extraversion (Jokela and Keltikangas-Järvinen, 2011). Sensation seeking (or subcomponent of disinhibition) and extraversion have been associated with testosterone (Daitzman et al., 1978; Alvergne et al., 2010; Campbell et al., 2010) but not in all studies (Rosenblitt et al., 2001). Sensation seeking, in turn, has also been associated with purported proxies of testosterone levels, including hand grip strength (Fink et al., 2010) and the 2:4 digit ratio that is assumed to reflects prenatal exposure to testosterone (Voracek et al., 2010). Together these findings imply that testosterone may be most relevant to personality dimensions characterized by novelty seeking and sensation seeking.

Novelty seeking has been associated with dopaminergic functioning (Gerra et al., 2000; Hansenne et al., 2002). Testosterone, in turn, has been shown to modulate the dopaminergic system and dopamine-dependent behaviors (Aubele and Kritzer, 2011; Volman et al., 2011; Bell and Sisk, 2013). It is therefore possible that the association between testosterone and novelty seeking is mediated by levels of dopamine in the central nervous system (Cloninger, 1987).

Interestingly, there was a within-individual association between higher testosterone and higher reward dependence, which was not observed in the overall regression model. Reward dependence reflects the importance of social rewards to the individual (Cloninger, 1987). Testosterone has previously been associated with social behaviors (Daitzman et al., 1978), and its association with reward dependence might be related to such interpersonal and affiliative behaviors directed toward other people. However, this association seems to reflect time-dependent variations within individuals rather than associations between individuals that are related to stable between-individual differences in levels of testosterone. On the other hand, the associations between reward dependence and levels of free testosterone were quite similar in the overall and within-individual analyses, suggesting that levels of total versus free testosterone may be differently associated with social behaviors assessed by reward dependence. Overall, testosterone has been connected with several social behaviors and interactions, but often these associations involve status competition (Eisenegger et al., 2011).

There are limitations that need to be acknowledged when interpreting the current findings. First, although we did have two measurement times, which allowed us to examine the time-varying nature of the associations between testosterone and temperament, our study was correlative and cannot thus demonstrate causality. Second, our study only examined the main effect associations between testosterone and temperament, but these associations might be modified by various environmental circumstances. Third, the testosterone data were available only for the male subjects. On the side of methodological strengths, our study was based on a large population-based sample with a longitudinal study design and repeated measurements of testosterone and temperament, the measurement of both total and bioavailable free testosterone.

The results of our study add to previous literature on testosterone and temperament by showing that novelty seeking appears to be the main temperament dimension related to differing levels of testosterone between and within individuals. Other temperament dimensions may be only weakly or conditionally associated with testosterone. Further studies examining potential modifying environmental factors and time-varying associations between testosterone and temperament may provide important additional insights in understanding the neuroendocrinology of personality functioning.

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The study sponsors had no role in study design; in the collection, analysis, and interpretation of data; in the writing of the report; and in the decision to submit the paper for publication.

Conflicts of interest

None declared.

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