



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.

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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 (Gruza 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°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,

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