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Latent trait testosterone among 18–24 year olds: Methodological considerations and risk associations

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ABSTRACT

The study investigated the relationship between latent trait testosterone (LTT) and risk-taking among 126 youth (*M* age = 21.34 years; 56% female; 52% African American). Latent state-trait (LST) modeling isolates observed variance of samples via their correlations into (1) a latent trait testosterone (LTT) factor capturing individual differences, and (2) a component of state testosterone factor (LST) capturing state-specific situational or environmental influences and random error variances. Participants provided four laboratory (20 min apart) and four home (waking, 20-min post-waking, noon, evening) salivary samples (later assayed for testosterone). Participants reported risk-taking tendencies and behaviors via an Audio Computer Assisted Self-Interview. Behavioral risk was measured using the Balloon Analog Risk Task. Results revealed: (1) LTT model invariance (operated similarly) for females and males; (2) LTT accounted for 18–89% (home samples) and 61–95% (lab samples) of the variance in testosterone levels, and (3) LTT was associated with risk-seeking behaviors and the strength of this association was similar across males and females. LST Modeling has potential to advance our understanding of testosterone-behavior associations to new limits by estimating stable *trait-like* components of the variance in testosterone levels.

1. Introduction

Behavioral endocrinology has had a challenge consistently estimating the shared variation (or common variance) between testosterone and behavior (see Mazur and Booth, 1998; Archer, 1991, 2006 for reviews). Among the reasons for cross-study inconsistency is that individual differences in testosterone levels are influenced by a variety of factors, including social situational–contextual effects, diurnal and pulsatile secretion, sex differences, and maturational–developmental effects (Nelson, 2005). Technological advances have made the assessment of testosterone possible in saliva samples (e.g., Granger et al., 1999, 2004). Sampling saliva is minimally invasive and the low burden this places on participants enables multiple samplings to be obtained. The capacity to obtain multiple measurement time points creates opportunity to apply modern statistical methods, latent state-trait modeling (LST), to estimate latent factors reflecting stable-trait like and state-like components of the variance in testosterone levels. When LST has been applied to model individual differences in salivary cortisol, latent trait cortisol (LTC) estimates account for between 10% and 55% of the variance, and the findings linking LTC to individual differences (e.g., risk behavior and early adversity) have been intriguing (see Shirtcliff et al., 2005; Doane et al., 2015; Giesbrecht et al., 2015; Stroud et al., 2016). To the best of our knowledge, no study has yet demonstrated the feasibility of modeling latent trait testosterone (LTT), or explored links between LTT and risk-taking tendencies (e.g., impulsivity) and behaviors (e.g., sexual, substance use). In theory, the application multiple measurement time points and LST modeling has potential to increase the probability of revealing testosterone-behavior associations. In the present study we begin to address this possibility and potentially important knowledge gap.

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1.1. Testosterone and risk-taking proclivities and behaviors

Numerous studies have investigated the relationship between testosterone and sexual and health risk-taking behaviors and tendencies. In general, testosterone has been positively related to sexual risk-taking and is more often related to dominance and competition for status than aggression per se (see Mazur and Booth, 1998 for review; Booth et al., 2005; Archer, 2006). However, there are multiple caveats that call into question any broad sweeping generalizations. First, findings are less than consistent across studies and the magnitude of the effect size is small to modest at best. Second, the clear majority of empirical attention has focused on males. The studies that do include females suggest not only sex-differences in testosterone levels, and measurement validity, but also in the behavioral correlates and concomitants (Kivlighan et al., 2005; Cohan et al., 2003; Shirtcliff et al., 2002). Third, the findings also suggest that the expression of testosterone and risk taking behavior is highly dependent on context. In a seminal study, Booth and colleagues (Booth et al., 2003) reported that the association between higher testosterone and risk-taking behavior among adolescent boys was moderated by quality of parent-child relationships. The testosterone-behavior association was only observed when levels of parental intimacy and monitoring were low. Finally, there is evidence of a U-shaped association between testosterone levels and problem behavior. Males with the highest testosterone had the highest rates of substance and alcohol use, unemployment, divorce, but men with the lowest testosterone levels are less likely to seek and form romantic partnerships and more likely to express symptoms of depression (Booth et al., 2005).

1.2. Sexual dimorphism

There is a pronounced and well-characterized developmental sexual dimorphism in testosterone levels (Nelson, 2005). The sex difference emerges during the pubertal transition and is caused by distinctly different mechanisms of testosterone production for males (i.e., leydig cell secretion) versus females (i.e., peripheral metabolism) after adolescence. Given this dimorphism there is potential of confounding caused by the interactive effect of testosterone and biological sex on risk taking behavior. To mitigate this potential confounding influence, statistical models are often run separately by biological sex. This tactic of separate modeling, however, has inherent limitations. First, it reduces the sample size and power to detect effects. Second, when a significant effect of testosterone on behavior is discovered for one sex but not the other, we cannot draw the conclusion that the association between testosterone and risk taking behavior is different for males and females because a direct test was not conducted for biological sex differences. Alternatively, a multi-group approach could be employed to test whether the association between testosterone and risk taking is indeed the same for males and for females. That is, we could test whether one unit change in testosterone corresponds to the same unit of change in risk-seeking in both males and females. These models will still account for different mean levels in testosterone for females and males.

1.3. Latent state-trait modeling and testosterone

Latent state-trait (LST) modeling (Steyer et al., 2012; Steyer et al., 1989)—permits the identification of a stable indicator of individual differences in testosterone levels. Specifically, LST modeling isolates observed variance of samples via their correlations into (1) a latent trait testosterone (LTT) factor, which captures individual differences by drawing from the commonalities among samples in reference to the grand mean (or whole sample); and (2) a component of state testosterone factor (LST), which captures state-specific situational or environmental influences (that may change from moment-to-moment or day-to-day) and random error variances. Several prior studies have identified trait indicators of cortisol using LST modeling (Essex et al., 2011; Kertes and van Dulmen, 2012; Kirschbaum et al., 1990; Shirtcliff et al., 2012; Shirtcliff et al., 2005; Doane et al., 2015) as a departure from the common practice of representing the basal level as the average of multiple measures (El-Sheikh et al., 2008). Although this approach as utility, the averaged basal level is a mixture of "true score" and noise (i.e., measurement errors). This issue can be addressed using structural equation modeling (SEM) to represent the "true score" via latent variables and differentiating trait, state, and error variance components. "Trait-like" stable sources of variance have been shown for salivary cortisol (Booth et al., 2008; Kirschbaum et al., 1990; Shirtcliff et al., 2005) and alpha amylase (Out et al., 2011, 2013).

To the best of our knowledge no studies have yet applied LST to model individual differences in testosterone. LST modeling of testosterone would seem to have high potential. Studies suggest a much stronger association in testosterone levels within and across days than is commonly reported for cortisol (Granger et al., 2004), and LST modeling has the capacity to take into account biological sex via (1) testing whether sex invariance holds in the measurement model of trait like testosterone and (2) testing whether sex invariance holds in the structural model for the association between trait like testosterone and risk taking tendencies and behaviors.

1.4. The present study

As part of a larger study (The HONESTY Project: HOrmone and NEurological Survey of Texting Youth) designed to examine biosocial determinants of risk-taking decision-making (NIDA # K01DA029571), we collected saliva samples from 126 participants (56% female – $n = 70$, ages 18–24 years old). All samples were later assayed for testosterone. Based on prior literature we hypothesized that an LTT would explain a considerable portion of the variance in testosterone levels, that there would be measurement invariance for LTT across sex, that higher salivary testosterone would be associated with greater sexual and substance use risk-taking behaviors and underlying impulsivity and sensation seeking proclivities, and associations between testosterone and risk behaviors will be stronger for males relative to females.

2. Methods

2.1. Participants

Participants were 126 unmarried (70 females) 18–24 year olds (M age = 21.34 years; SD = 1.88 years; 41.3% white; 52.4% black). Recruitment strategies included advertisement in local newspapers and social media, flyers, and peer referrals. Quota sampling was used to ensure representation across age bands, biological sex, and race. Slightly more than half of the sample identified as Black (52.4%) and female (55.6%). To establish a heterogeneous sample of youth regarding risk behaviors (risk avoidant to risk taking), participants were recruited from within an urban city characterized by high STI and HIV prevalence rates, drug use, and crime as well as surrounding counties marked by fewer risk outcomes. Over half (54%) of participants reported free or reduced lunch eligibility as a minor, 48 percent lived with both biological parents at age 14, and 41 percent were not currently enrolled in school either part- or full-time.