Are sexual desire and sociosexual orientation related to men’s salivary steroid hormones?

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Abstract
Although it is widely assumed that men’s sexual desire and interest in casual sex (i.e., sociosexual orientation) are linked to steroid hormone levels, evidence for such associations is mixed. Consequently, we tested for both longitudinal and cross-sectional relationships between salivary testosterone, cortisol, reported sexual desire and sociosexuality in a sample of 61 young adult men, each of whom was tested weekly on up to five occasions. Longitudinal analyses showed no clear relationships between steroid hormones and self-reported sexual desire or sociosexual orientation. Cross-sectional analyses showed no significant associations between average hormone levels and self-reported sexual desire. However, some aspects of sociosexuality, most notably desire for casual sex, were related to men’s average hormone levels. Men with higher average testosterone reported greater desire for casual sex, but only if they also had relatively low average cortisol. These results support a Dual Hormone account of men’s sociosexuality, in which the combined effects of testosterone and cortisol predict the extent of men’s interest in casual sex.

Introduction
Inspired by findings from non-human primates (reviewed in Roney, 2018), many recent studies have used longitudinal designs to investigate the hormonal correlates of within-woman changes in both sexual desire and openness to uncommitted sexual relationships (i.e., sociosexual orientation). Results on this topic have been somewhat mixed, however. Most studies suggest a general increase in sexual desire when estradiol is high and/or progesterone is low (Arslan et al., 2018; Jones et al., 2018; Roney & Simmons, 2013; 2016; Shirazi et al., 2019a; van Stein et al., 2019). By contrast, other work has reported that openness to uncommitted sexual relationships, but not general sexual desire, increases when estradiol is high (Shirazi et al., 2019b) or that desire for sex with women’s primary partner increases when progesterone is high (Grebe et al., 2016).
Somewhat surprisingly, there have been far fewer longitudinal studies of the hormonal correlates of within-man changes in sexual desire and sociosexual orientation. One study suggested that testosterone and cortisol together negatively predict solitary sexual desire, but not dyadic sexual desire (Raisanen et al., 2018). A second longitudinal study did not find compelling evidence for a link between sociosexual orientation and testosterone (Gettler et al., 2019). Results of cross-sectional studies of the hormonal correlates of men’s sexual desire and sociosexual orientation are similarly mixed. Whereas positive associations between testosterone and solitary, but not dyadic, sexual desire have been reported in two studies (Das & Sawin, 2016; van Anders & Dunn, 2009), no associations between testosterone and solitary or dyadic sexual desire were observed in two other studies (van Anders et al., 2007; van Anders, 2012). Similarly, one study reported that sociosexual desire, but not sociosexual behavior or attitudes, was positively correlated with men’s testosterone (Edelstein et al., 2011), two studies found no compelling evidence for correlations between testosterone and sociosexual orientation (Kordsmeyer et al., 2018; van Anders et al., 2007), and one study found that testosterone was positively correlated with sociosexual desire, but negatively correlated with sociosexual behavior (Puts et al., 2015).

In light of the mixed results for steroid hormones and both men’s sexual desire and sociosexual orientation, we investigated possible relationships between within-subject changes in men’s salivary testosterone and cortisol and their reported sexual desire (assessed using the Revised Sexual Desire Inventory, Spector et al., 1996) and sociosexual orientation (assessed using the Revised Sociosexual Orientation Inventory; Penke & Asendorpf, 2008). We also investigated possible relationships between men’s average steroid hormone levels and their reported sexual desire and sociosexual orientation.

**Participants**
Sixty-one men (57 reporting being heterosexual, one reporting being homosexual, two reporting being bisexual, and one reporting being attracted to neither men nor women) participated in the study (mean age=22.2 years,
SD=3.32 years). None of these men were currently taking any form of hormonal supplement or had taken any form of hormonal supplement in the 90 days prior to participation. Participants took part in the study as part of a larger project investigating hormonal correlates of voice and face perception (Kandrik et al., 2016, 2017).

Procedure
Participants completed up to five weekly test sessions, which took place between 2pm and 5pm to minimize diurnal variation in hormone levels (Papacosta & Nassis, 2011). Fifty-seven of the participants completed more than one test session, with 50 of the participants completing all five test sessions.

During each test session, participants provided a saliva sample via the passive drool method (Papacosta & Nassis, 2011). Participants were instructed to avoid consuming alcohol and coffee in the 12 hours prior to participation and to avoid eating, smoking, drinking, chewing gum, or brushing their teeth in the 60 minutes prior to participation. They also completed the Sexual Desire Inventory (SDI-2) and Revised Sociosexual Orientation Inventory (SOI-R). The order in which participants provided saliva samples and completed the questionnaires was fully randomized. Questionnaire responses were collected using the Experimentum interface (DeBruine, 2019).

Sexual Desire Inventory (SDI-2)
The Sexual Desire Inventory (SDI-2) is a 14-item questionnaire that assesses general sexual desire (Spector et al., 1996). An example question is “When you are in romantic situations (such as a candle lit dinner, a walk on the beach, etc.), how strong is your sexual desire?”, to which participants responded using a 1 (no desire) to 9 (strong desire) scale. As well as providing a score for total sexual desire (M=60.11, SD=16.33), the SDI-2 also provides separate scores for desire for sexual activity with another person (dyadic sexual desire, M=38.55, SD=10.04) and desire for sexual activity by oneself (solitary sexual desire, M=11.75, SD=3.93).
Revised Sociosexual Orientation Inventory (SOI-R)
The Revised Sociosexual Orientation Inventory (SOI-R) is a nine-item questionnaire that assesses openness to uncommitted sexual relationships (Penke & Asendorpf, 2008). Each item is answered using a 1 to 5 scale. The SOI-R has three components (desire, attitude, and behavior). The desire component consists of 3 items (e.g., “In everyday life, how often do you have spontaneous fantasies about having sex with someone you have just met?”), for which 1 on the response scale corresponds to “never” and 5 corresponds to “nearly every day” (M=3.25, SD=0.95). The attitude component consists of 3 items (e.g., “Sex without love is OK”), for which 1 on the response scale corresponds to “totally disagree” and 5 corresponds to “totally agree” (M=3.52, SD=1.15). The behavior component consists of 3 items (e.g., “With how many different partners have you had sex within the past 12 months?”), for which 1 on the response scale corresponds to “0 sexual partners” and 5 corresponds to “8 or more sexual partners” (M=2.17, SD=0.81). Scores for each component are calculated by averaging the individual scores for the 3 relevant items (M=2.98, SD=0.75).

Assays
Saliva samples were immediately frozen and stored at -32°C until being shipped, on dry ice, to the Salimetrics Lab (Suffolk, UK) for analysis. There they were assayed using the Salivary Testosterone Enzyme Immunoassay Kit 1-2402 (M = 178.26 pg/mL, SD = 41.97 pg/mL, sensitivity<1.0 pg/mL, intra-assay CV=4.60%, inter-assay CV=9.83%) and Salivary Cortisol Enzyme Immunoassay Kit 1-3002 (M = 0.19 μg/dL, SD = 0.11 μg/dL, sensitivity<0.003 μg/dL, intra-assay CV=3.50%, inter-assay CV=5.08%).

Hormone levels more than three standard deviations from the sample mean for that hormone or where Salimetrics indicated levels were outside the sensitivity range of the relevant ELISA were excluded from the dataset (<1% of hormone measures were excluded for these reasons; one cortisol value and four testosterone values). The descriptive statistics given above do not include these excluded values.
For *current* hormone levels, values for each hormone were centered on their subject-specific means to isolate effects of within-subject changes in hormones. They were then scaled so the majority of the distribution for each hormone varied from -0.5 to 0.5 to facilitate calculations in the linear mixed models. To calculate *average* hormone levels, the average value for each hormone across test sessions was calculated for each man. These values were then centered on their grand means and scaled so the majority of the distribution for each hormone varied from -0.5 to 0.5. Plots of these values are given in our Supplemental Materials and show no evidence of skew.

**Analyses**

We used a linear mixed model to test for possible effects of hormone levels on reported intrasexual competitiveness. Analyses were conducted using R version 3.3.2 (R Core Team, 2016), with lme4 version 1.1-13 (Bates et al., 2014) and lmerTest version 2.0-33 (Kuznetsova et al., 2013). Data files and analysis scripts are publicly available at https://osf.io/d79px/.

**Results**

Scores on the SDI-2 subscales and each subscale of the SOI-R were analyzed separately. Predictors were current testosterone, current cortisol, and their interaction, and average testosterone, average cortisol, and their interaction. No covariates were included in the model. Random slopes were specified maximally following Barr et al. (2013) and Barr (2013). Full model specifications and full results for each analysis are given in our Supplemental Information.

**Total sexual desire (total score on SDI-2)**

There were no significant effects of current hormone levels (testosterone: estimate = 1.29, t = 0.46, p = .648; cortisol: estimate = -2.07, t = -0.93, p = .375; interaction: estimate = 27.04, t = 1.51, p = .137) or average hormone levels (testosterone: estimate = 2.09, t = 0.18, p = .860; cortisol: estimate = -17.12, t = -1.16, p = .250; interaction: estimate = -74.81, t = -1.42, p = .160).
**Solitary sexual desire (score of solitary subscale on SDI-2)**
There were no significant effects of current hormone levels (testosterone: estimate = -1.10, t = -1.33, p = .186; cortisol: estimate = -0.51, t = -0.74, p = .458; interaction: estimate = 5.97, t = 1.07, p = .287) or average hormone levels (testosterone: estimate = 1.45, t = 0.53, p = .597; cortisol: estimate = -3.75, t = -1.10, p = .276; interaction: estimate = -16.55, t = -1.37, p = .177).

**Dyadic sexual desire (score of dyadic subscale of SDI-2)**
There were no significant effects of current hormone levels (testosterone: estimate = 3.96, t = 1.69, p = .102; cortisol: estimate = -1.18, t = -0.71, p = .481; interaction: estimate = 22.27, t = 1.63, p = .104) or average hormone levels (testosterone: estimate = -0.75, t = -0.10, p = .918; cortisol: estimate = -10.17, t = -1.12, p = .267; interaction: estimate = -38.65, t = -1.20, p = .237).

**Sociosexual orientation (total score on SOI-R)**
There were no significant effects of current hormone levels (testosterone: estimate = -0.05, t = -0.38, p = .703; cortisol: estimate = -0.13, t = -1.06, p = .297; interaction: estimate = 0.47, t = 0.54, p = .589) or main effects of average hormone levels (testosterone: estimate = 0.91, t = 1.79, p = .079; cortisol: estimate = -0.20, t = -0.31, p = .755). However, there was a significant negative interaction between average testosterone and average cortisol levels (estimate = -6.17, t = -2.72, p = .009). Only men with relatively low levels of cortisol showed a positive relationship between testosterone and sociosexual orientation.

**Sociosexual behavior (score of behavior subscale on SOI-R)**
There were no significant effects of current hormone levels (testosterone estimate = -0.14, t = -1.00, p = .318; cortisol: estimate = -0.04, t = -0.37, p = .715; interaction: estimate = 1.70, t = 1.71, p = .109) or average hormone levels (testosterone: estimate = 0.76, t = 1.24, p = .220; cortisol: estimate = 0.29, t = 0.38, p = .705; interaction: estimate = -0.32, t = -0.12, p = .906) were significant.

**Sociosexual attitude (score of attitude subscale of SOI-R)**
There were no significant effects of current hormone levels (testosterone: estimate = 0.12, t = 0.45, p = .654; cortisol: estimate = 0.09, t = 0.44, p = .666; interaction: estimate = -1.50, t = -0.98, p = .329) or significant main effects of average testosterone (estimate = 1.24, t = 1.67, p = .100) or average cortisol (estimate = -0.29, t = -0.32, p = .753). However, there was a significant negative interaction between average testosterone and average cortisol levels (estimate = -11.83, t = -3.59, p = .001). Only men with relatively low levels of cortisol showed a positive relationship between testosterone and sociosexual attitude.

**Sociosexual desire (score of desire subscale of SOI-R)**

There were no significant effects of current testosterone (estimate = -0.00, t = -0.01, p = .985), the interaction between current testosterone and current cortisol (estimate = 1.83, t = -1.08, p = .294), or average hormone levels (testosterone: estimate = 0.91, t = 1.45, p = .153; cortisol: estimate = -0.75, t = -0.95, p = .348). However, there was a significant negative interaction between average testosterone levels and average cortisol levels (estimate = -6.36, t = -2.27, p = .027). Only men with relatively low levels of cortisol showed a positive relationship between testosterone and sociosexual desire. There was also a significant negative effect of current cortisol (cortisol: estimate = -0.49, t = -2.07, p = .044).

**Robustness checks**

Repeating the analyses described above, this time removing men who did not report being heterosexual from the dataset, showed the same patterns of significant and non-significant results.

**Discussion**

Our analyses showed no clear effects of within-subject changes in men’s testosterone, cortisol, or their interaction on any aspects of sociosexuality or sexual desire. There was a weak negative effect of current cortisol on sociosexual desire, but this was not robust to correction for multiple tests (uncorrected p-value = .044). Thus, we did not replicate Raisanen et al’s (2018) recent finding that within-subject changes in men’s solitary, but not
dyadic, sexual desire track changes in their testosterone and cortisol. However, our null results for sociosexuality and within-subject changes in men’s testosterone are consistent with similar null results reported by Gettler et al. (2019). While our results support the recent proposal that changes in endogenous steroid hormones contribute little (if at all) to within-subject changes in men’s sociosexuality (Gettler et al., 2019), they do not support the claim that endogenous steroid hormones contribute to the regulation of men’s sexual desire (Raisanen et al., 2018).

Our analyses of responses on the SDI-2 also showed no significant cross-sectional associations between aspects of men’s sexual desire and average steroid hormones. Thus, we did not replicate previous findings in which men with higher average testosterone reported greater solitary sexual desire (Das & Sawin, 2016; van Anders & Dunn, 2009). However, the null results for cross-sectional associations between aspects of men’s sexual desire and steroid hormones are consistent with similar null results that have been reported in other studies (van Anders et al., 2007; van Anders, 2012). Collectively, these results suggest that associations between average steroid hormone levels and sexual desire in men are not robust.

Some previous studies have reported that men with higher average testosterone levels score higher on sociosexual desire (Edelstein et al., 2011; Puts et al., 2015), but lower on sociosexual behavior (Puts et al., 2015). These results have been interpreted as evidence for a feedback loop in which rising testosterone levels increase sociosexual desire, but that engaging in sexual behavior causes men’s testosterone levels to fall (Puts et al., 2015). Neither our longitudinal nor cross-sectional analyses of men’s sociosexuality support this proposal. However, our null results for sociosexuality and men’s average testosterone levels are consistent with similar null results reported in other studies (Kordsmeyer et al., 2018; van Anders et al., 2007).

Intriguingly, we found that average testosterone was positively related to sociosexual attitudes, sociosexual desires, and global sociosexual orientation (i.e., total scores on the SOI-R) among men with relatively low cortisol.
Although we did not predict this result, we note here that the interactions between average testosterone and average cortisol for sociosexual attitudes and global sociosexual orientation would be significant even if Bonferroni-corrected for multiple comparisons. Some previous research suggests that the combination of high testosterone and low cortisol is associated with status-related behaviors (see Mehta & Prasad, 2015, for a review of this Dual Hormone Hypothesis). If this is the case, our results present preliminary evidence that attitudes to uncommitted sexual relationships might be similarly related to high testosterone and low cortisol. Further research would be necessary to shed further light on this possibility. Previous studies investigating possible associations between steroid hormones and men’s sociosexuality may not have detected these relationships because they did not consider the interaction between average testosterone and average cortisol (Kordsmeyer et al., 2018; van Anders et al., 2007).

Strengths of the current study include the longitudinal analyses and consideration of testosterone, cortisol, and their interactions. However, there are limitations that could be addressed in future work. For example, replicating the cross-sectional findings for sociosexuality in a larger sample may clarify whether our results are robust or false positives.

In conclusion, we did not replicate previous results linking aspects of men’s sexual desire to their steroid hormones. However, we did find evidence that aspects of men’s sociosexual orientation, most notably their attitude to casual sex, was predicted by the interaction between average testosterone and average cortisol. Men with higher average testosterone levels reported more positive attitudes to casual sex, but only if they also had relatively low average cortisol. While such a pattern of results is arguably consistent with the Dual Hormone Hypothesis of men’s competitive behaviors, further work is needed to establish whether this pattern of results is robust.
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