Available online at www.sciencedirect.com
ScienceDirect
Hormones and Behavior 51 (2007) 286–291
Hormones and Behavior
www.elsevier.com/locate/yhbeh

Testosterone levels in women and men who are single, in long-distance relationships, or same-city relationships

Sari M. van Anders *, Neil V. Watson

Department of Psychology, Simon Fraser University, 8888 University Drive, Burnaby BC, Canada V5A 1S6

Received 3 November 2006; revised 15 November 2006; accepted 16 November 2006

Abstract

Research points to an association between testosterone (T) and partnering in some women and men, and this association has been interpreted as an effect of either relationship status (i.e. differences in relationship status lead to differences in T) or relationship orientation (i.e. T is associated with the likelihood of entering relationships). To address whether physical partner presence was associated with decreased T, we examined T levels in people (72 women; 49 men) who were single, in long-distance relationships, or in same-city relationships. No participants were using exogenous hormones, including hormonal contraceptives. Participants provided a saliva sample and responded to questions about their relationship status. Single men had higher T than long-distance and same-city partnered men, which supports the relationship orientation interpretation. In contrast, same-city partnered women had lower T than single women and women in long-distance relationships, which supports the relationship status interpretation. We conclude that physical partner presence is not necessary to see an association between partnering and hormones in men (since same-city and long-distance partnered men had similar T levels), but may be necessary in women (since same-city partnered women had lower T than long-distance partnered women).

Keywords: Testosterone; Androgen; Partnering; Relationship status; Relationship orientation; Gender; Sex; Single; Pair bond

Introduction

Previous research has established that heterosexual partnered men (whether married or in long-term relationships) exhibit lower testosterone (T) than heterosexual unpartnered men (e.g. Booth and Dabbs, 1993; Mazur and Michalek, 1998; Gray et al., 2002; Burnham et al., 2003; Gray et al., 2004a,b). More recent research has extended this pattern to non-heterosexual women (i.e. higher T in unpartnered non-heterosexual women compared to partnered non-heterosexual women), and suggested that partnering and T are not associated in heterosexual women or non-heterosexual men (van Anders and Watson, 2006a).

Direction of effect is still unclear as there have been fewer longitudinal than cross-sectional studies, and these have provided mixed results. Our previous study found no evidence that entering a relationship decreased T, but did find evidence that lower T predicted entering a relationship (van Anders and Watson, 2006a). Individuals who were unpartnered at both baseline and follow-up had higher T at both time points than individuals who were unpartnered at baseline and partnered at follow-up or partnered at both time points. However, sample size was small and the time between baseline and follow-up testing was 6–12 months, so it remains possible that larger samples or longer latencies between baseline and follow-up might show state effects. However, if T predicts likelihood of partnering as this research suggests, it may be that relationship *orientation* is associated with T instead of, or in addition to, relationship status. Relationship orientation refers to the likelihood of entering relationships (e.g. lower T influences long-term partnering), and relationship status refers to the current relationship situation (e.g. being in a relationship is associated with a decrease in T).

In support of a relationship orientation interpretation, Booth and Dabbs (1993) did find that men with higher T were less likely to have married and more likely to have divorced than

* Corresponding author. Fax: +1 604 291 3427.
E-mail address: saria@sfu.ca (S.M. van Anders).

0018-506X/$ - see front matter © 2006 Elsevier Inc. All rights reserved.
doi:10.1016/j.yhbeh.2006.11.005

lower T men. Additionally, Gray et al. (2004a) found that T does not differ in men between days spent at work and days spent with their wives. As well, Mazur and Michalek (1998) found that T was lower in stably married men compared to stably unmarried men. However, they suggest that divorce may be associated with increased T, though their evidence shows that T is especially elevated near the divorce, and levels off. Additionally, they note that T levels in unwed men were not much different from men who changed marital status. Additionally, Marazziti and Canale (2004) have found that T levels increased in partnered men after the intense early period of falling in love is over, and decreased in women over the same time, such that T levels did not show long-term effects of being in a relationship.

It is unclear from this evidence whether relationship status does affect T, and it remains to be seen whether change in partnered status is associated with endocrine changes in addition to divorce and its concomitant social disruption or the process of falling in love. Mazur and Michalek (1998)′s study is suggestive of possible effects of relationship status on T. It differed from van Anders and Watson (2006a) in that the former had a dramatically larger sample size, an older sample, divorce (as opposed to break-up), and a longer latency between additional sampling time points. In summary, there appear to be multiple pieces of evidence pointing to an association between T and relationship orientation, as well as some potentially pointing towards T and relationship status. There are reasons to expect effects of relationship status on T, since many social behaviors can affect T in humans (for reviews, see Archer, 2006; van Anders and Watson, 2006b) and other species (e.g. birds, Wingfield et al., 1990). However, these same citations also generally show some support for effects of T on social variables, though generally less strongly so in humans.

The evidence supporting associations between partnering and T has been interpreted in light of varying theoretical perspectives. The testosterone trade-off framework suggests that higher T should be associated with competitive behaviors or contexts (i.e. related to resource acquisition or defense) and lower T should be associated with bond-maintenance behaviors or contexts (i.e. related to intimate, caring contact) (van Anders and Watson, 2006b). In terms of partnering, competitive refers potentially to looking for additional partners or jealousy of individuals' own partners, and bond-maintenance refers to intimate and caring contact with individuals' own partners. Lower T and 'bond-maintenance' should characterize partnered individuals in a general sense, and higher T and 'competitive' should characterize unpartnered individuals in a general sense, though there are, of course, likely to be mediating and moderating variables.

Based on the association between lower T and partnering, we hypothesized that if relationship *orientation* is associated with T, then individuals in long-distance and same-city relationships should display similar levels of T, and levels that are lower than single individuals. That is, if lower T is associated with a bond-maintenance relationship orientation, then physical partner presence should not affect the partnering-T association. If relationship *status* is associated with T, then individuals who are in long-distance relationships should display higher T than individuals in same-city relationships, and comparable levels (perhaps) to single individuals. That is, if the lower T found in partnered individuals is associated with their daily behaviors or partner cues, then physical partner presence should affect this partnering-T association.

Methods

Participants

Participants were recruited through the undergraduate psychology participant pool, where they were prescreened for exogenous hormone use, and from the larger community through poster advertisements. Participants from the community received small reimbursements and participants from the psychology pool received course credit for participation.

Participants included 72 women (mean age = 20.79 years; min = 17 years, max = 32 years) and 49 men (mean age = 21.47 years, min = 17 years, max = 40 years). Five women were using hormonal contraceptives and were excluded from the analyses, and one man was using medications that affect sex steroids. These participants were excluded, leaving 67 women and 48 men in the analyses.

Our participants identified their sexual orientation via self-report and the Kinsey questions of sex-directed fantasy and behavior (Kinsey et al., 1948). We imposed dichotomous labels such that participants who scored 0 or 1 on both measures were categorized as heterosexual and individuals who scored 2 or more on one or both measures were categorized as non-heterosexual (van Anders and Watson, 2006a; van Anders and Hampson, 2005). This categorization resulted in 43 heterosexual women, 24 non-heterosexual women, 28 heterosexual men, and 10 non-heterosexual men. This provided a very liberal estimate of non-heterosexual participants: using self-identification, there were two gay men, three queer women, and four bisexual/bicurious women.

Our participants had all graduated from high school, and 61 had at least 1 year of university or college (or similar), 10 were college/university graduates, two had at least 1 year in graduate or professional school, and three had a graduate degree. The majority (n = 112) of our participants were currently students, but many of them (n = 51) were employed in diverse occupations. Participants were diverse ethnically[1].

Participants self-identified their relationship status, and we further determined whether they were same-city or long-distance relationships by asking whether their partners lived in the same city as them. We had participants who were single and not currently seeing people (28 women; 21 men), same-city partnered (15 women; 12 men), or long-distance partnered (17 women; 11 men). Though we specifically recruited for single or long-term relationships (same-city or long-distance), seven women and four men who were dating participated, and we excluded them from subsequent analyses.

Materials and procedure

The procedures were subject to prior approval by the SFU Research Ethics Board. Participants were tested between 1200 and 1800 h to control for diurnal rhythms in T (except one participant at 23:30 and one at 11:15). Participants provided a saliva sample and completed a brief questionnaire about their demographics, health and background, and relationship status. We did not control for menstrual cycle phase as previous research has shown that these consistent but small effects do not need to be controlled unless menstrual cycle is

[1] Participants self-identified their ethnicity and these were their responses with n's in brackets: Chinese (30), Caucasian (29), Korean (6), Canadian (4), Asian (11), Anglo/Latin (1), Black (1), British/Canadian (1), Chinese/Italian (1), Croatian/Chinese (1), Dutch/First Nations (1), East Asian (1), East Indian (3), Egyptian (1), Hindi (1), Mexico (1), Indian (1), Jewish (1), Métis (1), Middle Eastern (1), Persian (1), Punjabi (Sikh) (1), Sinhalese (1), Turkish (1), Vietnamese (1).

of interest (Dabbs and de La Rue, 1990); we did collect information about menstrual cycles, however, as a potential control measure.

The questionnaire included questions about demographic variables (as per above), sleep–wake variables, weight and height to compute BMI (body mass index, a measure of weight corrected for height), and relationship variables: whether participants considered their partners to be partners for the long-term (yes, no); whether participants had sexual/romantic contact with non-partners during the relationship (no, once, rarely, sometimes, often, regularly); whether participants were sexually active with their partners (no, once/month, 2–3 times/month, once/week, 2–3 times/week, once/day, more than once/day); level of commitment to the relationship (Likert-type scale from 1=extremely to 7=not at all); likelihood of being together with partner 'forever' (same Likert-type scale); level of sexual attraction to partner over the past month (same Likert-type scale). People in long-distance relationships also indicated how often on average they saw their partners and estimated how long during each year they saw their partners in person. These measures were converted into days.

Saliva samples were collected in polystyrene tubes that had been pretreated with sodium azide, and frozen after collection at −20 °C until assay. Saliva was stimulated with the use of an inert gum (Trident cherry sugar-free). The samples were assayed in two batches for testosterone using radioimmunoassay at the Endocrine Core Lab at Yerkes National Primate Research Center, Emory University, all in triplicate, using a modified kit from Diagnostic Systems Laboratories (Webster, TX). The sensitivity was 2–500 pg/mL at a 200 μL dose. The interassay coefficients of variation were 19.16% at 5.03 pg/mL, 15.08% at 170.81 pg/mL, and 16.40% at 25.31 pg/mL. The intra-assay coefficient of variation was 3.41% at 26.89 pg/mL.

Analyses were conducted with the Statistical Package for the Social Sciences (SPSS), v. 13.0. Overall effects were tested using analyses of variance (ANOVA) or covariance (ANCOVA), or independent *t*-tests when appropriate. Group differences were evaluated using the LSD (Least Significant Difference) test after significant omnibus analyses. Correlations were evaluated using Pearson′s Product Moment Correlations.

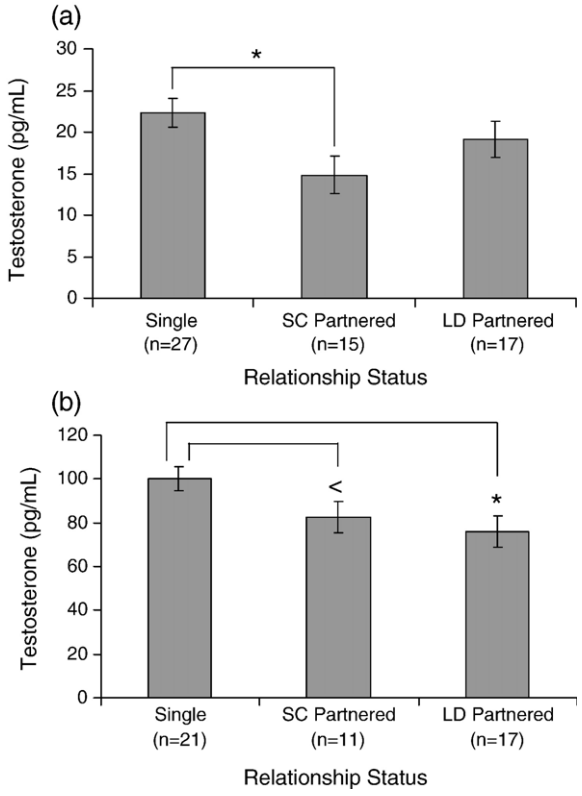

Fig. 1. Mean testosterone levels by relationship status with standard error bars for (a) women, adjusted for age; and (b) men, adjusted for age and time-of-waking. 'SC Partnered' indicates 'Same-City Partnered', 'LD' indicates 'Long-Distance Partnered'; '*' indicates a significant difference at $p<.05$; '<' indicates a trend with $p<.10$.

Results

Participants in long-distance relationships spent an average of 70 days per year together, and participants in same-city relationships spent an average of 243 days per year together, and this was significantly different, $t(37)=5.01$, $p<.001$.

Women

To see if women's T differed as a function of relationship status (single, same-city partnered, long-distance partnered), we conducted an ANCOVA, with age as a covariate. There was a significant overall difference in women's T, $F(2,55)=3.28$, $p=.045$, partial $\eta^2=.107$ (see Fig. 1a). Women in long-distance relationships did not have significantly different T than women in same-city relationships, $p=.166$, or women who were single, $p=.287$. However, women in same-city relationships did have significantly lower T than single women, $p=.013$.

To ensure that our findings were not the result of other variables or confounds, we controlled for additional variables to see if the pattern of results changed. Because women in these various types of relationships might show different sleep–wake patterns (e.g. late night contacts with long-distance partners) and sleep patterns are associated with T (Axelsson et al., 2005), we conducted an additional ANCOVA controlling for time of waking, but this did not change the pattern of significant results. Previous research has also shown that women's sexual orientation may moderate associations between partnering and T (van Anders and Watson, 2006a), but controlling for sexual orientation in an additional ANCOVA did not change the pattern of significant results either, likely because we had only a small number of self-identified non-heterosexuals in the study. There was no significant difference between long-distance and same-city partnered women's BMI, $t(30)=-.10$, $p=.918$.

To see if there were differences in relationship variables between women in long-distance and same-city relationships that could explain the pattern of findings, we analyzed the following using independent *t*-tests. There were no significant differences (or trends) between women in same-city or long-distance relationships in whether the women considered their partner for the long-term (statistic could not be calculated because SDs=0 in both groups), sexual contact with non-relationship partners, $t(29)=.20$, $p=.846$, commitment to relationship, $t(30)=.94$, $p=.354$, the reported likelihood that the women and their partners will be together 'forever', $t(30)=-.45$, $p=.654$, level of sexual attraction to their partner over the past month, $t(30)=.15$, $p=.886$, or length of relationship, $t(30)=.24$, $p=.809$. The correlations between T and number of days spent together in the past year were not significant in all partnered women, $r(22)=-.15$, $p=.474$, or in long-distance partnered women, $r(13)=-.11$, $p=.697$, or same-city partnered women alone, $r(7)=.41$, $p=.271$. The correlations did not become larger when age was controlled in partial correlations.

Men

We conducted an ANCOVA to see if men's T differed as a function of their relationship status, with age controlled. There was a trend towards a significant overall effect, $F(2, 39)=3.08$, $p=.057$. We then also entered time of waking as a covariate (see above discussion), and the ANCOVA showed a significant overall effect, $F(2, 38)=3.78$, $p=.032$, partial $\eta^2=.166$, so all further values are adjusted for age and time of waking (see Fig. 1b). T levels in single men were significantly higher than long-distance partnered men, $p=.012$, and showed a trend towards being significant higher than same-city partnered men, $p=.072$. There was no significant difference between same-city partnered men or long-distance partnered men, $p=.505$.

As with women, we controlled for additional variables to see if other variables accounted for the pattern of results in men. There was no significant difference between long-distance and same-city partnered men's BMI, $t(20)=-.14$, $p=.894$. Entering sexual orientation as a covariate did not change the pattern of significant results, again likely because we only had a small sample of self-identified non-heterosexual participants.

To see if there were differences in relationship variables between men in long-distance and same-city relationships that could explain the pattern of findings, we analyzed the following using independent *t*-tests. There were no significant differences (or trends) between men in same-city or long-distance relationships in whether the men considered their partner for the long-term, $t(10)=-1.49$, $p=.167$, sexual contact with non-relationship partners, $t(10)=-1.15$, $p=.274$, commitment to relationship, $t(21)=.34$, $p=.738$, the reported likelihood that the men and their partners will be together 'forever', $t(21)=1.53$, $p=.142$, or length of relationship, $t(21)=.41$, $p=.688$. However, there was a significant difference in men's sexual attraction to their partners over the past month, $t(21)=2.11$, $p=.047$, such that same-city partnered men reported significantly less sexual attraction to their partners than long-distance partnered men. The correlations between T and number of days spent together in the past year were not significantly correlated in all partnered men, $r(18)=.27$, $p=.258$, or in long-distance partnered men, $r(7)=-.10$, $p=.803$, or same-city partnered men alone, $r(9)=.37$, $p=.266$. The correlations did not become larger when age was controlled in partial correlations.

Multiple relationships

There was a small number of individuals ($n=6$) in relationships who had additional casual or long-term relationships. These included five individuals in long-distance relationships (three men; two women), and one woman in a same-city relationship. Excluding these participants did not change the pattern of results, except to change the overall ANCOVA in the women to a trend.

Discussion

The present study examined testosterone (T) levels in individuals (women and men) who were single, in long-distance relationships, or in same-city relationships. We tested two hypotheses: (1) relationship *orientation*: T should be similar in partnered individuals (regardless of physical partner presence) and lower than T levels in single people; (2) relationship *status*: T should be lower in same-city partnered individuals than single or long-distance partnered individuals. Our results do not directly answer the question of causality, but shed light on the issue. Relationship orientation may reflect individual propensities towards entering relationships and/or individual attractiveness for relationships, and our study does not address this distinction.

We found that partnered men displayed lower T than single men, and this was true for men with same-city relationships or long-distance relationships. This was true despite same-city partnered men reporting less sexual attraction to their partners than long-distance partnered men, and that long-distance partnered men must have inevitably had less (or no) sexual contact with their partners, which are interesting findings in themselves, and suggest that differences in sexual activity or attraction are not associated with differences in T levels. There were no other differences between the men in relationships, including current/long-term commitment and length of relationship. One caveat is the sample size of 11 men in each partnered group. However, mean T was nonsignificantly lower in long-distance partnered men suggesting that sample size was not contributing to the null difference between partnered men's T and single men's T. The data are in accord with previous findings that are suggestive of an association between T and relationship orientation. For example, van Anders and Watson (2006a) found that T levels predicted entering relationships but no evidence that entering a relationship decreased T; Booth and Dabbs (1993) found that T levels predicted divorce and singlehood; and Mazur and Michalek (1998) also found that T levels predicted divorce.

There is one previous finding that suggests that changes in relationship status cause changes in T, such that T is increased around divorce (Mazur and Michalek, 1998). These authors note that T in unwed men is similar to men who change marital status, which arguably supports a relationship orientation interpretation. Additionally, T levels do not differ in heterosexual men between days spent with partners vs. days spent at work (Gray et al., 2004a), which suggests that partner directed behaviors do not lead to lower T over the day. McIntyre et al. (2006) have shown that partnered but not single men with a less restricted SOI (sociosexual orientation: a measure of reported willingness to engage in sex outside of a committed, emotionally involved relationship, Simpson and Gangestad, 1991) exhibit higher T, which is suggestive that relationship orientation, regardless of relationship status, is associated with T. Our suggestion that evidence points to an association between relationship orientation and T does not negate the idea that behaviors related to partnering affect men's T. We have elsewhere posited that they should (van Anders and Watson, 2006b), and there is evidence that they do (e.g. Roney et al., 2003). It is possible that relationship status does affect T, and studies that address relevant cues other than long-term physical partner presence, short-term partner-directed behaviors, or

relationship commitment (which we have not found to be correlated with T in our studies) should prove instructive. One possibility is that behaviors directed at attracting non-partner individuals increase T and account for higher T in single men (van Anders and Watson, 2006b), as Roney et al. report that 'show-off' behaviors directed towards women increase T.

We found that same-city partnered women display lower T than long-distance partnered or single women, despite no differences in parameters like current/long-term commitment, sexual attraction, or length of relationship. This was surprising, since the one previous study including women found an effect only in non-heterosexual women (van Anders and Watson, 2006a); however, the finding from our present data did not disappear when sexual orientation was controlled, suggesting that partnering and T may be associated across women. In the previous study, van Anders and Watson found that heterosexual women's means were in the expected direction but did not significantly differ. It remains possible that the previous study included long-distance partnered women in the partnered category (potentially inflating their T levels), obscuring any association between T and partnering. This is speculative, and further study including women is clearly warranted. The data suggest that physical partner presence is associated with decreased T, which supports a relationship status interpretation in women. One interesting possibility is that long-distance partnered women's higher T may be associated with increased frequency of masturbation, as research has found preliminary evidence of an association between masturbation-induced orgasms and higher T (van Anders et al., under review). Replication and further empirical data are needed before possible explanations are proposed for sex differences in T-partnering associations.

The issue of physical partner presence is promising for future study. Most same-city partnered participants did not live with their partners, and previous studies have not identified whether partners were live-in or not. Apparently, live-in partners are not necessary for partnered men to display lower T than single men, since we found that long-distance partnered men had lower T than single men. However, this may be a mediating factor for women, as same-city partnered women exhibited lower T than single or long-distance partnered women. We only had a small sample of same-city partnered women with live-in partners, but their T levels appeared to be lower than same-city partnered women who did not live with their partners (15.33 vs. 18.57 pg/mL), though not significantly so. However, the estimated number of days spent with partners did not correlate with T in partnered women or by relationship type, though numbers were small for correlational analyses. It would be interesting to further examine the issue by comparing T in women with live-in and non-live in (but same-city) partners of similar relationship lengths, commitment, and ages.

Evidence from various sources suggests that sexual experience may sensitize or organize the endocrine system of human and non-human males in terms of future endocrine or behavioral responses to reproductive/sexual opportunities (e.g. Clancy et al., 1988; Domjan et al., 1992; Pfeiffer and Johnston, 1994; Roney et al., 2003). Is this true for pair bonding experience? And, exposure to female cues often is associated with increased T in males (humans: Roney et al., 2003; hamsters: Pfieffer and Johnston, 1992), but we see lower T in partnered men; do cues need to be from unfamiliar partners in humans and other species? Counter to our findings, male golden hamsters housed with or without females show no difference in baseline androgens (Pfieffer and Johnston, 1992). So, research with pair bonding species may provide insights as to how T is associated with partnering in males and potentially partner presence in females.

Findings from the present study suggest that physical partner cues – salient signals of relationship status – do not affect the partnering-T association in men. In conjunction with previous evidence, this is suggestive of an association between relationship orientation and T. Do men with lower T display more of a bond-maintenance relationship orientation than their higher T counterparts? Are these men more likely to be selected for long-term relationships? In women, our findings suggest that physical partner cues are associated with reduced T, which is suggestive of an association between relationship status and T. Do women with live-in partners have lower T than women with partners who live in the same city but not the same residence? How and why these sex differences occur remains to be seen, and studies of within-sex associations between T and partnering will likely be suggestive.

Acknowledgments

This research was supported by Discovery Grant 0194522 from the Natural Sciences and Engineering Research Council of Canada (NSERC) to N.V. Watson. S.M. van Anders was supported by a War Memorial Scholarship from IODE Canada. Salivary assays were conducted by the Endocrine Core Assay Lab at Yerkes Primate Research Center, Emory University. We would like to thank N. Macdonald, S. Orford, G. Panduri, R. Park, N. Schmidt, and C. Viray for help with data collection. We would also like to thank P.T. Ellison, P.B. Gray, and three anonymous reviewers for suggestions on earlier drafts.

References

Archer, J., 2006. Testosterone and human aggression: an evaluation of the challenge hypothesis. Neurosci. Biobehav. Rev. 30, 319–345.

Axelsson, J., Ingre, M., Akerstedt, T., Holmback, U., 2005. Effects of acutely displaced sleep on testosterone. J. Clin. Endocrinol. Metab. 90 (8), 3535–4530.

Booth, A., Dabbs Jr., J.M., 1993. Testosterone and men′s marriages. Soc. Forces 72, 463–477.

Burnham, T.C., Flynn Chapman, J., Gray, P.B., McIntyre, M.H., Lipson, S.F., Ellison, P.T., 2003. Men in committed romantic relationships have lower testosterone. Horm. Behav. 44, 119–122.

Clancy, A.N., Singer, A.G., Macrides, F., Bronson, F.H., Agosta, W.C., 1988. Experiential and endocrine dependence of gonadotropin responses in male mice to conspecific urine. Biol. Reprod. 38, 183–192.

Dabbs Jr., J.M., de la Rue, D., 1990. Salivary testosterone measurements among women: relative magnitude of circadian and menstrual cycles. Horm. Res. 35 (5), 182–184.

Domjan, M., Akins, C., Vandergriff, D.H., 1992. Increased responding to female stimuli as a result of sexual experience: tests of mechanisms of learning. Q. J. Exp. Psychol. 45, 139–157.

Gray, P.B., Kahlenberg, S.M., Barrett, E.S., Lipson, S.F., Ellison, P.T., 2002. Marriage and fatherhood are associated with lower testosterone in males. Evol. Hum. Behav. 23, 193–201.

Gray, P.B., Campbell, B.C., Marlowe, F.W., Lipson, S.F., Ellison, P.T., 2004a. Social variables predict between-subject but not day-to-day variation in the testosterone of US men. Psychoneuroendocrinology 29, 1153–1162.

Gray, P.B., Flynn Chapman, J., Burnham, T.C., McIntyre, M.H., Lipson, S.F., Ellison, P.T., 2004b. Human male pair bonding and testosterone. Hum. Nat. 15, 119–131.

Kinsey, A.C., Pomeroy, W.B., Martin, C.E., Gebhard, P.H., 1948. Sexual Behavior in the Human Male. WB Saunders, Philadelphia.

Marazziti, D., Canale, D., 2004. Hormonal changes when falling in love. Psychoneuroendocrinology 29 (7), 931–936.

Mazur, A., Michalek, J., 1998. Marriage, divorce, and male testosterone. Soc. Forces 77 (1), 315–330.

McIntyre, M.H., Gangestad, S.W., Gray, P.B., Chapman, J.F., Burnham, T.C., O'Rourke, M.T., Thornhill, R., 2006. Romantic involvement often reduces men′s testosterone levels—but not always: the moderating role of extrapair sexual interest. J. Pers. Soc. Psychol. 91 (4), 642–651.

Pfieffer, C.A., Johnston, R.E., 1992. Socially stimulated androgen surges in male hamsters: the roles of vaginal secretions, behavioral interactions, and housing conditions. Horm. Behav. 26, 283–293.

Pfeiffer, C.A., Johnston, R.E., 1994. Hormonal and behavioral responses of male hamsters to females and female odors: roles of olfaction, the vomeronasal system, and sexual experience. Physiol. Behav. 55, 129–138.

Roney, J.R., Mahler, S.V., Maestripieri, D., 2003. Behavioral and hormonal responses of men to brief interactions with women. Evol. Hum. Behav. 24, 365–375.

Simpson, J.A., Gangestad, S.W., 1991. Individual differences in sociosexuality: evidence for convergent and discriminant validity. J. Pers. Soc. Psychol. 60, 870–883.

van Anders, S.M., Hampson, E., 2005. Testing the prenatal androgen hypothesis: measuring digit ratios, sexual orientation, and spatial abilities in adults. Horm. Behav. 47 (1), 92–98.

van Anders, S.M., Watson, N.V., 2006a. Relationship status and testosterone in North American men and women of diverse orientations: cross-sectional and longitudinal findings. Psychoneuroendocrinology 31, 715–723.

van Anders, S.M., Watson, N.V., 2006b. Social neuroendocrinology: effects of social behaviors and contexts on sex steroids in humans. Hum. Nat. 17 (2), 212–237.

van Anders, S.M., Hamilton, L.D., Schmidt, N., Watson, N., under review. Associations between testosterone secretion and sexual activity in women and men.

Wingfield, J.C., Hegner, R.E., Dufty Jr., A.M., Ball, G.F., 1990. The "challenge hypothesis": theoretical implications for patterns of testosterone secretion, mating systems, and breeding strategies. Am. Nat. 36, 829–846.