Hormones and Behavior 65 (2014) 401–407

Contents lists available at ScienceDirect

Hormones and Behavior

journal homepage: www.elsevier.com/locate/yhbeh

Regular article

Dyadic associations between testosterone and relationship quality in couples

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ARTICLE INFO

Article history:
Received 20 July 2013
Revised 31 January 2014
Accepted 7 March 2014
Available online 17 March 2014

Keywords:
Testosterone
Couples
Relationships
Dyadic
Satisfaction
Commitment
Gender
Sex
Individual differences

ABSTRACT

Testosterone is thought to be positively associated with "mating effort", or the initiation and establishment of sexual relationships (Wingfield et al., 1990). Yet, because testosterone is negatively associated with nurturance (van Anders et al., 2011), high levels of testosterone may be incompatible with relationship maintenance. For instance, partnered men with high testosterone report lower relationship quality compared to partnered men with low testosterone (e.g., Booth and Dabbs, 1993). Findings for women are inconsistent, however, and even less is known about potential *dyadic* associations between testosterone and relationship quality in couples. In the current report, we assessed relationship satisfaction, commitment, and investment in heterosexual couples and tested the hypothesis that these aspects of relationship quality would be negatively associated with an individual's own and his/her partner's testosterone levels. We found that testosterone was in fact negatively associated with relationship satisfaction and commitment in both men and women. There was also evidence for dyadic associations: Participants' satisfaction and commitment were negatively related to their *partners*' levels of testosterone, and these associations were larger for women's than men's testosterone. Our findings are consistent with the idea that high testosterone may be incompatible with the maintenance of nurturant relationships. The current findings also provide some of the first evidence for dyadic associations between testosterone and relationship quality in couples, highlighting the interdependent nature of close relationship processes and the importance of considering this interdependence in social neuroendocrine research.

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Introduction

Testosterone has been associated with trade-offs between sexuality and competition, on the one hand, and nurturance and caregiving, on the other hand (van Anders et al., 2011; Wingfield et al., 1990). Although testosterone appears to promote the establishment of sexual relationships in humans and other primates (e.g., Beehner et al., 2006; Slatcher et al., 2011), high levels of testosterone may be associated with poorer functioning in ongoing nurturant relationships. Consistent with this idea, men and women in committed, monoamorous relationships typically have lower testosterone compared to those who are single (e.g., Gettler et al., 2011; Gray et al., 2006; van Anders and Goldey, 2010). Among already partnered men, those with lower testosterone show indicators of better functioning in normative Western relationships—including higher marital satisfaction, lower interest in extra-dyadic sex, and lower likelihood of divorce—compared to partnered men with higher testosterone (e.g., Booth and Dabbs, 1993; Edelstein et al., 2011; Julian and McKenry, 1989; McIntyre et al., 2006; Perini et al., 2012).

These findings may reflect declines in testosterone associated with long-term relationships. For instance, men in more established relationships tend to have lower testosterone than those in newer relationships (Gray et al., 2004; McIntyre et al., 2006). Longitudinal research similarly suggests that men's testosterone levels increase prior to divorce and decrease following remarriage (Mazur and Michalek, 1998). Taken together, these findings suggest that contexts associated with nurturance can produce declines in testosterone (van Anders et al., 2011; Wingfield et al., 1990). Higher levels of testosterone could also lead to declines in relationship quality. For instance, testosterone administration is associated with decrements in relationship-promoting behavior (e.g., empathy, trust; Bos et al., 2012), which could interfere with romantic relationship functioning. Thus, although the direction of causality has not yet been established, there are reasons to expect that testosterone would be negatively associated with relationship quality, at least

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http://dx.doi.org/10.1016/j.yhbeh.2014.03.003
0018-506X/Published by Elsevier Inc.

among men. The few relevant studies that have included women do not provide consistent evidence linking women's testosterone with relationship functioning (e.g., Booth et al., 2005; Cohan et al., 2003; Hooper et al., 2011), so it is not yet clear whether and how these associations may differ by sex[1].

Given the inherent interdependence of romantic relationships, an individual's relationship quality might also be associated with his/her *partner's* testosterone levels, perhaps via the mechanisms described above. For example, a more satisfied relationship partner might be more likely to behave in a nurturant, responsive manner than a less satisfied partner (Feeney and Collins, 2001), leading to declines in his/her partner's levels of testosterone. Testosterone could also have inhibitory influences on nurturant behavior. For example, among fathers, baseline testosterone levels are negatively associated with responsiveness toward infants (e.g., Fleming et al., 2002; Weisman et al., 2014). This kind of relationship-promoting behavior could, in turn, enhance partner perceptions of relationship functioning (Collins and Feeney, 2000).

Relationship scientists emphasize the importance of considering couple members' interdependence (Rusbult and Van Lange, 2003), including in research on biological processes (Loving and Campbell, 2011). However, to our knowledge, only one study has examined associations between testosterone and relationship quality *within* couples (Booth et al., 2005). In a sample of parents, Booth et al. (2005) found that husbands' testosterone was negatively associated with their own and their wives' marital quality, but only among a subset of husbands who also experienced “role overload”. Wives' testosterone was largely unrelated to their own or their husbands' marital quality. Although these findings provide preliminary evidence for dyadic associations between (men's) testosterone and relationship quality, it should be noted that the data were not analyzed using dyadic data-analytic techniques that account for couple members' interdependence. That is, both relationship quality and testosterone were significantly positively correlated within couples, but this statistical interdependence was not accounted for in subsequent analyses, complicating the interpretation of any observed within-couple effects. Additionally, the authors used a somewhat complex measure of marital quality, collapsing across (potentially distinct) measures of love, conflict, satisfaction, and disagreement management. Finally, all participants were parents, who typically have lower testosterone and poorer relationship quality compared to non-parents (e.g., Gray et al., 2006; Perini et al., 2012). Any of these factors could have obscured more direct associations between testosterone and relationship quality, including those between women's testosterone and relationship outcomes.

The goal of the current report was, therefore, to investigate dyadic associations between testosterone and romantic relationship quality. We assessed relationship satisfaction, commitment, and investment in 39 couples and tested the hypothesis that these indices of relationship quality would be negatively associated with an individual's own and his/her partner's testosterone levels.

Methods

Participants and procedure

Participants ($N = 78$; 39 couples) were part of a larger study of neuroendocrine responses to intimacy. Only data from the initial laboratory session are included here; other data from this project have not yet been reported elsewhere. The couples were recruited via flyers and online advertisements and they received monetary compensation for participating. Participants with physical conditions (e.g., polycystic ovary syndrome) or those taking medications that could affect hormones (including hormonal contraceptives) were ineligible. One same-sex couple was tested but not included because our dyadic data-analytic approach required that couples be distinguishable on some variable (in our case, participant sex). A second couple did not follow the study procedures and was thus excluded.

Couples' relationship length ranged from two months to seven years ($M = 19.21$ months; $SD = 20.15$). Three couples were married or engaged and two couples were parents. Women's age ranged from 18 to 32 ($M = 21.31$ years, $SD = 2.88$); men's age ranged from 18 to 31 ($M = 22.18$ years, $SD = 2.89$). The majority of participants (84%) were undergraduate or graduate students. Participants were asked to self-report their race or ethnicity, and we categorized their responses as 49% Caucasian non-Hispanic, 23% Asian/Asian–American, 4% Hispanic, and 20% mixed or other ethnicities (4% did not report ethnicity).

Women were also asked to report the date that their last period began (to the best of their recollection), the date that they expected their next period to begin, and the length of their typical menstrual cycle. Additionally, we contacted women two to four weeks post-study to determine when their first post-study menstrual period began. Based on this information, we calculated the approximate number of days from the beginning of each woman's last menstrual period until her laboratory session ($M = 12.97$ days; $SD = 8.70$; range = 1 to 33). Women's salivary testosterone shows small changes as a function of menstrual-cycle phase (e.g., Faria et al., 1992; Liening et al., 2010), and there is some evidence that women's relationship quality is higher, and sexual desire is lower, during the luteal phase (when progesterone levels are at their peak; Bäckström et al., 1983) compared to other cycle phases (Jones et al., 2005; Roney and Simmons, 2013). Thus, in the current study, we assessed days since last menstruation to explore possible associations between women's cycle phase and both partners' relationship quality.

All procedures were approved by the University of Michigan Institutional Review Board. Sessions were conducted between February and July, and between the hours of 12:00 h and 19:00 h to control for circadian changes in testosterone. The couples attended the laboratory session together and they were asked to refrain from eating, drinking (except for water), smoking, or brushing their teeth for one hour prior to their session. After providing informed consent, participants completed the measures of relationship quality (as part of a larger battery of questionnaires relevant to the larger study) and provided one baseline saliva sample.

Materials

We used three subscales from the widely used Investment Model Scale (IMS; Rusbult et al., 1998) to assess participants' relationship quality. The 10-item *satisfaction* subscale ($\alpha = .94$) includes items such as “My relationship is close to ideal” and “Our relationship makes me very happy”. The 7-item *commitment* subscale ($\alpha = .88$) includes items such as “I want our relationship to last forever” and “I feel very attached to our relationship—very strongly linked to my partner”. The 10-item *investment* subscale ($\alpha = .88$) includes items such as “My partner and I share many memories” and “I have invested a great deal into our relationship that I would lose if the relationship were to end”. Participants rated the extent to which they agreed with each statement, using a 9-point Likert-type scale, ranging from 1 (*do not agree at all*) to 9 (*agree completely*).

Salivary testosterone: Collection and assessment

Participants rinsed their mouths with water and then used polypropylene tubes to collect 5 mL of saliva. After collection, the samples were frozen in our laboratory until further processing in the University of Michigan Core Assay Facility. Testosterone was assayed by radioimmunoassay using a commercially available kit from Siemens. Salivary testosterone assays are well-established, validated, and widely used in biobehavioral research (Schultheiss and Stanton, 2009). Salivary testosterone also correlates highly with free and total serum testosterone

[1] We use the term “sex” when discussing differences between men and women, but acknowledge that any differences cannot necessarily be attributed to innate or socialization processes.

(Granger et al., 2004; Khan-Dawood et al., 1984; Magrini et al., 1986; Swinkels et al., 1988). However, salivary testosterone measures are more sensitive to collection and storage artifacts compared to serum measures, and they may underestimate the strength of testosterone-behavior associations in women (Granger et al., 2004; Shirtcliff et al., 2002). Salivary measures may also underestimate the magnitude of menstrual-cycle changes in women's testosterone compared to serum measures (e.g., Dabbs and de La Rue, 1991).

The inter-assay coefficient of variation (CV) was 4.83% and 30.76% at high and low testosterone, respectively. The intra-assay CV was 12.51%. Analytical sensitivity ($B_0 - 2$ SD) was 1.14 pg/mL. The samples were assayed in duplicate, and the average of the duplicates was taken. It should be noted that our inter-assay CV is relatively high at low levels of testosterone. Comparable values have been reported in other studies that have assessed salivary testosterone in women, including studies that find associations between women's testosterone and other outcomes (e.g., Stanton et al., 2011). However, the high inter-assay CV suggests that there is more error in our estimation of women's versus men's testosterone values and, therefore, that our findings involving women's testosterone may be less reliable. Our intra-assay CV is also somewhat high but is comparable to other studies that include female participants (e.g., Jones et al., 2005; Liening et al., 2010).

One male participant had testosterone levels greater than three standard deviations above the mean (for men); this participant's value was winsorized to three standard deviations above the mean for further analyses (118.94 pg/mL in this sample). Results excluding this participant were very similar to those presented here, although some coefficients were smaller in magnitude.

Statistical analyses

Statistical analyses were conducted using SPSS (version 20) and SAS (version 9.3). For preliminary analyses, mean differences were assessed with independent samples *t*-tests and associations were assessed with correlations. Our main analyses focused on dyadic associations between testosterone and relationship quality. In our study, because individuals are nested within couples, observations from the couple members cannot be assumed to be independent, which violates assumptions of traditional regression approaches. Dyadic data analytic techniques are therefore more appropriate because they explicitly model the statistical interdependence between couple members and provide parameter estimates that control for within-couple associations. In the current study, we used multilevel modeling (MLM) procedures recommended for dyadic data analysis (i.e., SAS Proc Mixed; Kenny et al., 2006). MLM estimates both *actor effects* (associations between an individual's relationship quality and his/her own testosterone) and *partner effects* (associations between an individual's relationship quality and his/her partner's testosterone); both actor and partner effects account for the statistical interdependence between couple members. Relationship satisfaction, commitment, and investment served as dependent measures (for analytic purposes; we make no assumptions about the direction of causality).

Given that there are large sex differences in mean testosterone levels, some researchers standardize hormone levels within sex prior to analysis (e.g., Jones et al., 2005); however, others use raw values (e.g., Booth et al., 2005). Importantly, in our case, within-sex standardization is not advised for dyadic data analysis because this would make it impossible to assess sex differences in the association between testosterone and relationship quality (Kenny et al., 2006; see also Ronay and Carney, 2013). (Note, however, that the values we report when decomposing interactions with sex, below, are unaffected by the standardization of testosterone within sex.) Thus, predictor variables (partner/actor testosterone) were grand-mean centered and sex was contrast-coded ($-1 =$ men, $1 =$ women).

Results

Preliminary analyses

Means, standard deviations, and correlations among the primary study variables are presented by sex in Table 1. As expected, testosterone was significantly higher among men compared to women, $t\ (76) = 12.80$, $d = 2.94$, $p < .001$. Testosterone (analyzed separately by sex) was not significantly associated with time of day, participant's age, or body mass index (BMI), all r's < |.15|, p's > .36; thus, these variables were not included in subsequent analyses. There were also no significant sex differences in satisfaction or investment, all t's (76) < |.76|, p's > .19, although men reported lower levels of commitment compared to women, $t\ (76) = 2.22$, $d = .28$, $p < .05$ (see Table 1 for descriptives).

Within dyads, participants' satisfaction, commitment, and investment were significantly positively correlated (see Table 1), indicating substantial interdependence for these measures. Relationship length was positively correlated with investment for women, $r\ (39) = .39$, $p = .01$, and men, $r\ (39) = .53$, $p < .01$; however, relationship length was not significantly associated with any other study variables, p's > .12, so it was not included in further analyses.

Additionally, among women, cycle phase (i.e., days since onset of last menstruation) was not significantly correlated with testosterone levels, $r\ (39) = .15$, $p = .38$, satisfaction, $r\ (39) = .08$, $p = .63$, commitment, $r\ (39) = -.08$, $p = .59$, or investment, $r\ (39) = .22$, $p = .18$. Women's cycle phase was also unrelated to men's testosterone, $r\ (39) = .14$, $p = .39$, satisfaction, $r\ (39) = -.11$, $p = .52$, commitment, $r\ (39) = .13$, $p = .44$, and investment, $r\ (39) = -.08$, $p = .64$. We also tested whether days since last menstruation was associated with testosterone or relationship quality in a non-linear (i.e., quadratic) manner. Although visual inspection of the data suggested an expected mid-cycle increase, none of the quadratic associations were statistically significant. We additionally computed a categorical variable corresponding to approximate cycle phase (i.e., menstrual, follicular, luteal); however, this measure was not significantly associated with any study variables.[2] Thus, cycle phase was not included in subsequent analyses.

The correlations presented in Table 1 provide preliminary support for the idea that an individual's relationship quality is associated with his/her own *and* his/her partner's testosterone levels. Specifically, women's testosterone was negatively correlated with their own and their partner's satisfaction and commitment. Men's testosterone was negatively correlated with their own commitment and investment as well as with their partner's satisfaction, commitment, and investment. However, these zero-order correlations do not account for the interdependence within couples and may therefore overestimate within-couple associations. Thus, as described next, our primary analyses were conducted using a dyadic data-analytic approach that explicitly models and accounts for between-partner associations when estimating testosterone-relationship quality links.

Dyadic analyses

Separate multi-level models were conducted predicting satisfaction, commitment, and investment from sex, actor testosterone, partner testosterone, and the interactions between sex and actor/partner testosterone. As shown in Table 2, both actor and partner testosterone were negatively associated with satisfaction and commitment, indicating that participants were more satisfied and committed to the extent that they or their partner had lower testosterone. There were also

[2] Measures of women's estradiol were also available from the initial baseline samples. Visual inspection of our data suggests that estradiol showed an expected mid-cycle peak, but estradiol was not significantly related to days past last menstruation in either a linear or a quadratic manner. Given that our sample is relatively small, and that women's hormones were assessed at only one point in time, we did not use women's estradiol levels to assess menstrual cycle phase in this study.

Table 1
Descriptive statistics and correlations among primary study variables.

	1	2	3	4	5	6	7	*M*	*SD*
1. Women's testosterone								13.91	5.20
2. Women's satisfaction	−.44**							7.85	1.01
3. Women's commitment	−.34*	.51**						7.68	1.39
4. Women's investment	−.15	.33*	.47**					6.83	1.42
5. Men's testosterone	.28	−.37*	−.37*	−.35*				53.76	18.74
6. Men's satisfaction	−.51**	.71**	.41**	.23	−.29			7.66	1.21
7. Men's commitment	−.49**	.57**	.54**	.34*	−.36*	.73**		7.24	1.77
8. Men's investment	−.28	.39*	.56**	.39*	−.35*	.59**	.66**	6.83	1.42

Note. Testosterone values are reported in pg/mL. $N = 39$ couples.
* $p < .05$.
** $p < .01$.

significant sex × partner testosterone interactions predicting satisfaction and commitment, indicating that the strength of associations between partner testosterone and relationship outcomes differed between men and women. Decomposing these interactions revealed that the negative association between partner testosterone and satisfaction was significant for men, $b = -.11$, SE = .03, $t = -3.19$, $p < .01$; for women, the association between partner testosterone and satisfaction was also negative, but was marginally significant, $b = -.01$, SE = .01, $t = -1.78$, $p = .08$. These findings (depicted in Fig. 1) indicate that the association between partner testosterone and relationship satisfaction was stronger for men than for women.

Similarly, the negative association between partner testosterone and commitment was significant for men, $b = -.14$, SE = .05, $t = -2.88$, $p < .01$; for women, the association between partner testosterone and commitment was negative but was again marginally significant, $b = -.02$, SE = .02, $t = -1.93$, $p = .06$. As with satisfaction, these findings indicate that the negative association between partner testosterone and commitment was stronger among men than women. For relationship investment, the main effect of partner testosterone approached significance, $p = .06$, but there were no other significant effects or interactions, all p's > .48.

By conducting separate analyses on the three IMS subscales, we may increase the likelihood of Type I error. To correct for this possibility, we computed adjusted significance values using a Bonferroni procedure that corrects for the correlation among dependent measures and the number of statistical tests (as standard Bonferroni procedures may be too conservative with correlated dependent measures; see Sankoh et al., 1997). This correction resulted in an adjusted p-value of .03. All effects reported as statistically significant in the current report surpassed this threshold, with the exception of the main effects of actor testosterone on commitment, $p = .04$. Thus, our findings do not appear to be driven by increased Type I error due to multiple comparisons.

Moreover, because the IMS subscales were significantly intercorrelated, similar findings across subscales could reflect their statistical overlap rather than distinct associations with testosterone. Thus, we also computed a composite measure of relationship quality, including items from the satisfaction, commitment, and investment subscales ($\alpha = .94$). MLM results predicting this composite measure were very similar to those (described above) for satisfaction and commitment: there were significant main effects of actor, $b = -.03$, SE = .02, $t = -2.06$, $p < .05$, and partner testosterone, $b = -.06$, SE = .02, $t = -3.67$, $p < .01$. There was also a significant interaction between sex and partner testosterone, $b = -.04$, SE = .02, $t = -2.21$, $p < .05$, suggesting that the strength of associations differed between men and women. Decomposing this interaction revealed that the negative association between partner testosterone and the composite measure was significant for both men, $b = -.10$, SE = .03, $t = -3.02$, $p < .01$, and women, $b = -.02$, SE = .01, $t = -2.32$, $p < .05$. (The significant interaction with sex indicates that the association between partner testosterone and the composite measure is significantly larger among men than women.) Thus, these findings are consistent with those for the satisfaction and commitment subscales, indicating that partner effects were stronger for men than for women. Results from our multilevel analyses were virtually identical when relationship length, age, time of day, BMI, or women's cycle phase was covaried, suggesting that our findings were not influenced by these potential confounds.

Discussion

The current findings demonstrate that men and women who report higher relationship satisfaction and commitment have lower levels of testosterone than those who report lower satisfaction and commitment. Testosterone has previously been associated with men's relationship quality (e.g., Booth and Dabbs, 1993; Julian and McKenry, 1989), but to our knowledge, the current study is the first to demonstrate similar associations among women. Our findings also provide novel evidence that an individual's relationship quality is negatively associated with his or her *partner's* testosterone levels, and that such associations are stronger among men than women. Although relationship science has increasingly focused on biological processes, relatively few studies have done so from an explicitly dyadic perspective (Pietromonaco et al., 2013). Our findings highlight the potential contribution of this perspective and suggest several potentially fruitful avenues for further research.

For example, future research could examine the mechanisms that contribute to the dyadic associations we observed. Perhaps men and women with lower testosterone are more likely to engage in pro-

Table 2
Multilevel models predicting relationship quality.

	Satisfaction			Commitment			Investment		
	b	*SE (B)*	*t*	*b*	*SE (B)*	*t*	*b*	*SE (B)*	*t*
Sex	.05	.25	.20	.30	.45	.68	.10	.45	.22
Actor testosterone (T)	−.04	.01	−2.79**	−.05	.02	−2.15*	−.02	.02	−.70
Partner testosterone (T)	−.06	.02	−3.66**	−.08	.02	−3.33**	−.04	.02	−1.92
Sex × actor T	.03	.02	1.90	.02	.02	1.01	−.001	.02	−.05
Sex × partner T	−.05	.02	−2.60*	−.06	.03	−2.31*	−.01	.02	−.65

Note. $N = 78$; Effects are reported as unstandardized regression coefficients; Sex: −1 = women, 1 = men.
* $p < .05$.
** $p < .01$.

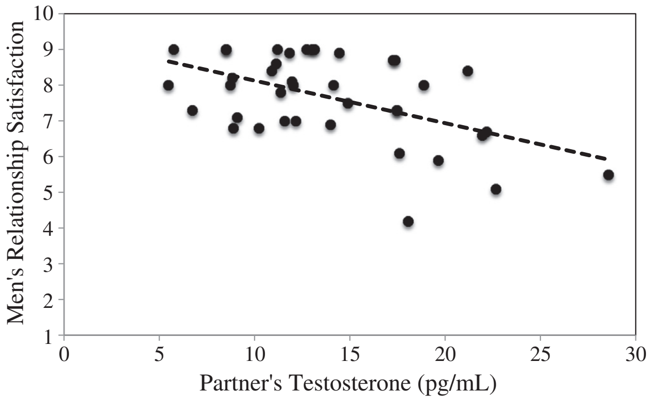

Fig. 1. The association between men's relationship satisfaction and their female partner's testosterone levels.

social or nurturant behavior (e.g., Harris et al., 1996; Weisman et al., 2014), and/or more likely to elicit such behavior from their partners, compared to individuals with higher testosterone. Either of these processes could enhance an individual's own perceptions of their relationship as well as the perceptions of his or her partner. Individuals with lower testosterone may also be more skilled than those with higher testosterone in reading others' emotions (Ronay and Carney, 2013), which could similarly enhance relationship perceptions (Noller, 1980). Alternatively, long-term satisfying relationships may lead to declines in testosterone. Longitudinal research suggests that men's testosterone declines with marriage, increases with divorce, and decreases with remarriage (Mazur and Michalek, 1998), suggesting that testosterone may be sensitive to changes in the quality of men's relationships. Caregiving behavior is also associated with declines in testosterone among new fathers (Gettler et al., 2011; Muller et al., 2009). Insofar as responsive caregiving enhances relationship satisfaction (Collins and Feeney, 2000), people with more responsive partners may show declines in testosterone over time.

It is also important to investigate why partner associations between testosterone and relationship quality were stronger among men than women. Perhaps women's higher testosterone reflects adrenally sourced stress responses (Chichinadze and Chichinadze, 2008), which could influence or be influenced by romantic relationship dynamics (Neff and Karney, 2009). It is also possible that, because women have lower circulating levels of testosterone compared to men, small differences in women's testosterone are more closely associated with behavioral outcomes (e.g., men's relationship quality) compared to such differences among men (Sherwin, 1988). Prior research suggests, for instance, that past sexual behavior is more closely tied to women's than men's baseline testosterone levels (Edelstein et al., 2011).

Of course, given the correlational nature of our study, we cannot determine the direction of causality between testosterone and relationship quality. There are reasons to expect that testosterone may be causally related to relationship satisfaction, such that higher testosterone would impair relationship processes. For example, recent experimental work suggests that testosterone administration decreases pro-social emotions such as trust, empathy, and generosity (Bos et al., 2012), which could negatively impact relationship functioning. Alternatively, relationship quality may influence testosterone levels. For example, longitudinal and experimental research demonstrates that nurturant interactions with infants decrease men's testosterone (Gettler et al., 2012; van Anders et al., 2012). Ultimately, testosterone-relationship quality associations are likely to be reciprocal, in that each mutually influences the other over time. Future studies could use longitudinal and/or experimental designs to better understand these causal and potentially reciprocal associations.

It is also important to note the limitations of our testosterone assays and assessment of women's menstrual cycle phase. Our assays were less reliable for women's than men's testosterone, suggesting that our values for women's testosterone may be less accurate. Although we nevertheless found associations between women's testosterone and both women's and men's perceptions of relationship quality, it will be important for future research to replicate our findings with larger samples and more reliable measures of testosterone (see Shirtcliff et al., 2002). Future research will also be necessary to understand whether and how menstrual-cycle changes in relationship quality and/or testosterone might contribute to associations between these two variables. Our cycle-phase estimation method was limited in that women may provide inaccurate estimates of their menstrual cycle and/or may have irregular cycles from month to month. Salivary measures of testosterone may also be less sensitive to menstrual-cycle effects compared to serum measures. Repeated neuroendocrine assessments throughout women's cycles would provide considerably more reliable measures; without such measures, our assessments reflect only rough estimates of women's cycle phase and thus it is difficult to draw firm conclusions from the null associations we observed here.

Furthermore, only regularly cycling women were included in the current study, so we cannot yet determine whether our findings can be generalized to women taking hormonal contraceptives. We focused on regularly cycling women because our own and others' research suggests that women's hormonal contraceptive use is associated with lower testosterone levels (see van Anders et al., 2014; Zimmerman et al., 2014) and attenuated testosterone responses (e.g., Goldey and van Anders, 2011; Lopez et al., 2009). Inter-individual variability in testosterone levels may also be lower among women taking hormonal contraceptives compared to normally cycling women (Liening et al., 2010). It is possible, then, that testosterone-relationship quality associations would be attenuated among women taking hormonal contraceptives. That is, normally cycling women's testosterone may be more responsive to and/or predictive of changes in relationship quality compared to women taking hormonal contraceptives. National surveys suggest that approximately 20–30% of sexually active women ages 15 to 44 are using some form of hormonal contraceptive at any given time, and nearly 80% have done so at some point in their lives (Jones et al., 2012). Moreover, women taking hormonal contraceptives may differ from regularly cycling women on demographic variables such as age, education, and socio-economic status (Daniels et al., 2013), which could influence the generalizability of our findings. For instance, the use of hormonal contraceptives is higher among younger versus older women and those with more versus less education (Jones et al., 2012), so our findings may be less representative of the broader population of young, college-educated women. Future research should examine whether and how use of oral contraceptives influences the link between women's hormones and relationship functioning.

It is also important to consider other unmeasured variables that may contribute to the associations we observed. For instance, stable personality characteristics, such as extraversion, dominance, and pro-sociality, have been linked with endogenous testosterone levels (Alvergne et al., 2010; Harris et al., 1996; Sellers et al., 2007); such traits also predict relationship outcomes (Roberts et al., 2007). Thus, testosterone and relationship quality may be related, at least in part, because of their common association with stable individual differences in personality. We are not aware of research that has explicitly tested this hypothesis, but it is an intriguing direction for further study.

Future research should also examine whether and how our findings apply to more established relationships and among older individuals. Our sample included primarily college students, and many were in relatively new relationships. Associations between testosterone and relationship quality may increase over time, due to the reciprocal influences discussed earlier. Alternatively, associations may decrease over time, as ongoing relational factors take precedence. Contextual factors, such as parenthood, may also become more influential in longer-term relationships, potentially overpowering the contribution of other individual differences. Against this backdrop, it is interesting to note that we did not observe significant associations between testosterone and relationship investment, the one IMS subscale that was significantly (positively) correlated with relationship length. Perhaps relationship investment is a better reflection of couples' shared history than of their current relationship dynamics. Longitudinal research could shed light on whether and how associations between testosterone and relationship quality change over time as relationships become more established.

Contextual factors may also underlie differences between our findings and those of the one prior study of couples' testosterone and relationship quality (Booth et al., 2005). Booth et al. examined associations between testosterone and relationship quality at two time points as part of a larger longitudinal study of married couples with children. For both husbands and wives, and at both time points, relationship quality was not significantly correlated with an individual's own or his/her partner's testosterone. However, among men who experienced high levels of "role overload" (i.e., the feeling of having too much to do and not enough time to do it), testosterone was negatively related to their own and their wives' relationship quality. That is, husbands and wives were less satisfied when husbands had high levels of testosterone *and* felt more burdened by life responsibilities. Our findings, in contrast, suggest a larger influence of women's testosterone on their partners' relationship quality than vice versa. This discrepancy suggests that men's testosterone may be more closely tied to women's relationship quality in more established relationships and/or among parents than among those in more recently established relationships. In fact, fathers' engagement in childcare is associated both with decreases in their own levels of testosterone (Gettler et al., 2011) and with their female partners' relationship satisfaction (e.g., Kalmijn, 1999). We did not measure role overload in our study, and this variable is arguably more meaningful in a sample of parents compared to college students (only a small minority of whom were parents), but it is possible that we would similarly find associations between men's testosterone and women's relationship quality among men who feel more burdened by life responsibilities. Nevertheless, it is also important to note that Booth et al.'s measure of relationship quality differed from ours in that their measure included constructs related to conflict, household decision-making, and disagreement management. Their analyses also did not account for couple members' interdependence. Thus, it will be important for future research to examine the conditions under which testosterone is associated with relationship quality, including a broader range of contextual and demographic characteristics.

In conclusion, our findings provide novel evidence for dyadic associations between testosterone and romantic relationship quality. In both men and women, testosterone was negatively associated with an individual's own relationship satisfaction and commitment. Similar associations were observed for partner levels of testosterone, and these associations were stronger among men than women. Together, these findings highlight the interdependent nature of romantic relationship processes and the importance of considering this interdependence, as well as sex differences, in neuroendocrine research.

Acknowledgments

This study was funded by a grant to Robin Edelstein and Sari van Anders from the Office of the Vice President for Research at the University of Michigan. William Chopik and Katherine Goldey were supported by Graduate Research Fellowships from the National Science Foundation. The funding sources had no further 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. We thank Emily Shipman and Lauren Hipp for their assistance with data collection, and the members of the Personality, Relationships, and Hormones Lab for their comments on earlier versions of this manuscript.

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