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Relationship quality and oxytocin: Influence of stable and modifiable aspects of relationships

Julianne Holt-Lunstad¹, Wendy C. Birmingham², and Kathleen C. Light³

Abstract
Prior studies report that couples with higher relationship quality show higher oxytocin (OT) levels, yet other studies report those with higher distress have increased OT. This study investigated these competing predictions in the context of a support intervention among 34 young married couples (N = 68). Preintervention marital quality (Dyadic Adjustment Scale) was examined for associations with plasma and salivary OT levels 4 weeks apart and for changes between these time points within the intervention group. High relationship quality, not distress, was associated with higher OT in both saliva and plasma at both time points. No significant interaction was found between marital quality and intervention condition; relationship quality and support intervention were both independently associated with higher postintervention OT levels.

Keywords
Cardiovascular, couples, dyadic adjustment, distress, intervention, oxytocin, relationship quality, social support

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There is now a robust literature linking social relationships to a better long-term health and increased longevity (Holt-Lunstad, Smith, & Layton, 2010; Uchino, 2006); however, less is known about the processes by which such effects occur. Given oxytocin (OT) is a critical mechanism in mammalian attachment and survival (Gimpl & Fahrenholz, 2001) and has been linked to both social bonding and stress regulation (Ishak, Kahlou, & Fakhry, 2011), it has been postulated as a possible factor linking social connectedness and long-term health (Gimpl & Fahrenholz, 2001; Insel & Young, 2001; Norman, Hawkley, Cole, Berntson, & Cacioppo, 2012). There is a large body of literature suggesting that relationship quality moderates the otherwise robust protective associations between social connections and morbidity and mortality (Robles, Slatcher, Trombello, & McGinn, 2014; Uchino, 2006). Although numerous studies link OT to social bonding particularly in animals (Carter, 1998; Insel & Young, 2001; Ross & Young, 2009), little research has examined the association between relationship quality and OT concentration in humans.

Although OT is often referred to as the “love hormone” or “cuddle hormone,” some studies have reported that higher levels of OT are associated with relationship distress (Tabak, McCullough, Szeto, Mendez, & McCabe, 2011; Taylor et al., 2006; Taylor, Saphire-Bernstein, & Seeman, 2010), anxiety (Hoge, Pollack, Kaufman, Zak, & Simon, 2008), and depression (Cyranowski et al., 2008). These latter findings have been interpreted as evidence that the oxytocinergic pathway is a stress-responsive system and is activated as part of the body’s secondary homeostatic efforts to dampen primary stress responses. Relationship distress, anxiety, and depression, however, have been linked to higher blood pressure and sympathetic and hypothalamic–pituitary–adrenal (HPA) axis activities (Grewen, Girdler, Hinderliter, & Light, 2004; Manthey et al., 2011), while higher OT in the absence of distress and depression has been linked to decreases in blood pressure, norepinephrine, and cortisol (Grewen, Girdler, Amico, & Light, 2005; Grewen & Light, 2011; Light, Grewen, & Amico, 2005; Linnen, Ellenbogen, Cardoso, & Joober, 2012). Based on the current evidence, it is presently unclear whether high relationship quality (a marker of social bonding) or low relationship quality (consistent with relationship distress) would be linked to higher OT levels.

Recent arguments suggest that inconsistencies in human studies of OT should not be discarded as error; rather there should be greater attention paid to both the stable person variables and the context (Bartz, Zaki, Bolger, & Ochsner, 2011). We therefore examine the effect of stable relationship characteristics (e.g., relationship quality) in the context of both basal levels and after a support enhancement intervention. Although many stable relationship factors (e.g., social support, loneliness, attachment) have been linked to important health outcomes, marital quality may be particularly predicative of OT, given its strong association with pair-bonding. Given substantial evidence that supportive social relationships are linked to greater longevity (Holt-Lunstad et al., 2010), it is also important to identify pathways associated with relatively stable relationship factors that may convey risk or protection as well as relationship factors that may be modifiable and in turn may potentially be used to reduce risk (Reblin & Uchino, 2008). We, therefore, also examined the potential interaction between relationship quality and support enhancement.

The present report builds upon a previously published behavioral intervention study which found that enhancing support through a warm touch intervention in married
couples resulted in greater circulating OT relative to nonintervention controls (Holt-Lunstad, Birmingham, & Light, 2008). The primary aim here was to examine the competing hypotheses regarding the association between relationship quality and circulating OT. More specifically, we addressed the following question: Will high relationship quality (e.g., supportive and warm) or low relationship quality (e.g., distressed) be linked to higher OT? The existing data set may provide a stronger test of this question relative to prior data in important ways. First, we examined circulating OT in both plasma (in the lab) and saliva (at home). Thus, we could thereby assess oxytocinergic activity in both the clinic environment (identical across subjects but may be atypical for participants) and home environment (which is typical for the participant and thus may more truly reflect what happens in daily life but may have features that vary across participants). Second, we obtained OT samples at two time points. This allowed us to examine an association between relationship quality and OT, and its stability over time. Third, the data include both members of the couple allowing us to examine this question in the context of the dyad and is not limited by gender. The secondary aim of this report was to examine whether relationship quality moderates the effect of enhancing support among couples (modifiable relationship factors) on OT levels. More specifically, does relationship quality influence the effectiveness of the intervention? If so, do well-adjusted couples or maladjusted (distressed) couples benefit more?

**Method**

**Participants**

A total of 36 healthy married couples (N = 72) aged 20–39 years (M = 25.2, SD = 3.8 years) who were married at least 6 months were recruited from the surrounding communities within reasonable traveling distance of the University. Self-reported inclusion criteria were used to select healthy participants: no existing hypertension, no prescription medication use except contraceptives, no past history of chronic disease with a cardiovascular (e.g., diabetes) or immune (e.g., cancer) component, and no recent history of psychological disorder (e.g., major depressive disorder). Volunteers were also excluded if pregnant, nursing, within 6 months postpartum, or planning to become pregnant within the time frame of the study. Of the initial qualifying couples, two couples’ data were dropped, one due to a death in the family and the other because the wife became pregnant. Thus, our final sample consisted of 34 couples (N = 68). Couples were randomized into two groups, with 20 couples in the intervention group and 14 couples in the “monitoring only” control group. Recruitment of subjects and study protocol were approved by the Brigham Young University institutional review board committee, and the Helsinki Declaration was followed.

**Procedures**

After prescreening, qualified participants were scheduled to come into the lab. After written consent was obtained, participants completed a packet of questionnaires (e.g., demographics, health history, relationship quality, and depression), and their height and
weight were measured. All couples underwent similar physiological assessment procedures (see Figure 1). Both pre- and postintervention, ambulatory blood pressure (ABP) was monitored for 24 hr, and five saliva samples for cortisol and α-amylase were obtained. Participants wore the ABP monitor outside the lab throughout the day and night—going about their normal activities. The five salivary samples were obtained at standardized times throughout the 24-hr period, which was used for assay of both cortisol and α-amylase. Plasma OT concentration was obtained once pre- (Time 1) and postintervention (Time 2) and obtained in the morning immediately preceding or following the ABP procedures. OT activity was also assessed by comparing salivary OT concentration obtained at home once during the first week (Week 1) and twice during the last week (Week 4) of the intervention/monitoring period. The intervention couples were instructed to obtain all three saliva samples at home on evenings when they practiced the intervention techniques, while the controls were simply told to collect their samples during evenings spent at home.

### Outline of intervention, home practice, and postintervention testing protocol

Following the baseline assessment procedure (approximately 1 week later), couples randomized to the intervention group were asked to come in for two 1-hr sessions to describe and allow hands-on practice of couple contact enhancement techniques—warm physical contact between marital partners that emphasizes warm touch as a way of communicating affection and support. Every effort was made to schedule the intervention training within 1 week of the Time 1 assessment, thus most were within the same week. During the first session (Week 1 of the intervention), couples were trained in listening touch (Rosen, 2003) where one increases awareness of the partner’s mood and body state through touching their partner’s neck, shoulders, and hands. Then, they were given an

![Flow diagram of research protocol. ABP: ambulatory blood pressure.](image)
audio recording to guide them in practicing these techniques at home and were instructed
to practice for 30 min 3 times/week for 4 weeks and to keep records of when they prac-
ticed and their mood state before and after practice. During the second session (Week 2
of the intervention), couples watched a short video of actors showing examples of sen-
sitive and insensitive touch, followed by a second video demonstrating neck, forehead,
and shoulder massages. Couples were then asked to follow along with the massage video,
practicing with their spouse under supervision of a trained staff member. Couples were
given the option either to add massage to their practice or to replace the listening touch
practice with massage during Weeks 2–4. In the control group, subjects were told not to
change anything about their normal behavior with their spouse and to simply keep a
diary of their physical affection and mood. They were asked to report this once a week
for 4 weeks. Postintervention testing was the same as Time 1 procedures for ABP and
saliva sampling.

Measures

Relationship quality. The Dyadic Adjustment Scale (DAS; Spanier, 1976) is a 32-item
instrument that assesses the marital quality and contains four subscales (Dyadic Consen-
sus, Dyadic Cohesion, Dyadic Satisfaction, and Affective Expression). It is currently the
most widely used measure of relationship quality in social and behavioral science and is
utilized as both a research and a clinical diagnostic tool to classify relationship distress
(Christensen et al., 2004; South, Krueger, & Iacono, 2009). The DAS has been found to
be valid and invariant across gender (South et al., 2009). Participants completed the DAS
once at the beginning of the study prior to randomization. The Cronbach’s $\alpha$ for this
study is $\alpha = .87$.

Cardiovascular functioning was measured using the Accutracker II (Suntech Medical
Instruments, Raleigh, Morrisville, North Carolina, USA) ABP monitor, which estimates
ambulatory readings of systolic BP (SBP) and diastolic BP (DBP) and is well validated
(Taylor, Chidley, Goodwin, Broeders, & Kirby, 1993). The monitor was set to randomly
take three readings per hour during the day (06:00–22:59) and two per hour during the
night (23:00–06:00).

Salivary cortisol and $\alpha$-amylase

We utilized standard salivary sampling procedures, sampling at standardized times to
account for diurnal effects. Samples were obtained at 07:00, 12:00, 17:00, 22:00, and
upon wakening, before they got out of bed. Salivary cortisol was measured with
a commercial immunoassay with chemiluminescence detection (IBL, Hamburg,
Germany). The assay has a lower detection limit of 0.1 nmol/l with intra- and interassay
coefficients of variations below 8%.

OT sampling procedures

A pre- and posttreatment plasma sample for OT concentration was obtained directly from a
single-stick venipuncture after 5 min of couples sitting close to each other holding hands.
The procedure was identical among all study participants and was utilized as an effort to minimize a stress response associated with the needle stick and maximize calm and connected state. The ability to calm one’s self or partner may be in part influenced by relationship quality. All plasma samples were obtained in the morning, typically between 7 a.m. and 9 a.m. Approximately 9 ml of blood was obtained from the antecubital vein in the non-dominant arm using ethylenediaminetetraacetic acid tubes. Plasma was immediately separated by centrifugation and frozen within 20 min. Samples were stored in −80 degree ultracold freezer prior to assay. The three home saliva samples for OT concentration were obtained by unstimulated passive drool collected into 4 ml plastic tubes. Samples were immediately frozen at the subjects’ homes and transported still frozen to the lab.

**OT bioassay procedures**

Plasma and saliva samples were then shipped to the University of North Carolina for assay using enzyme immunoassay (EIA) methods using an OT EIA kit from Assay Designs (Ann Arbor, Michigan, USA). Prior to assay, a recommended (McCullough, Churchland, & Mendez, 2013; Szeto et al., 2011) extraction step was performed. Extraction of OT peptide from the same subjects’ plasma and saliva samples was performed together in the same batch following the steps described in the manual accompanying the OT kit from Assay Designs, Inc. The result of this extraction was to concentrate the sample 3.2 times and to reduce matrix interference. Extraction efficiency was determined by spiking samples with a known amount of hormone and extracting with the other samples.

Next, OT levels in extracted plasma or saliva were measured in the same batch using assay kits and protocol obtained in 2006–2007 from Assay Designs, Inc. The endogenous OT hormone competes with OT linked to alkaline phosphatase for the OT antibody binding sites. After the overnight incubation at 4°C, the excess reagents were washed away and the bound OT phosphatase was incubated with substrate. After 1 hr, this enzyme reaction (which generates a yellow color) was stopped. The optical density (OD) was read on a Sunrise plate reader (Tecan, Research Triangle Park, Durham, North Carolina, USA) at 405 nm. The intensity of the color is inversely proportional to the concentration of OT in the sample. The hormone content (in pictogram per milliliter) was determined by plotting the OD of each sample against a standard curve. The kit states that the sensitivity limit of the assay with the current OT antibody (without correcting for the concentration produced by the extraction process) is more than twice as high as with the older antibody at 11.6 pg/ml. With correction for the extraction process as described above, we found that the lower limit of sensitivity was reduced to 2.0 pg/ml. The intra- and interassay variation for this assay is 4.8% and 8%, respectively, determined using a control sample with known OT concentration on each plate and in each run. Assay Designs reports cross-reactivity for similar neuropeptides found in mammalian sera to be less than .001.

**Analyses**

For our primary analyses, we used Proc Mixed (SAS Institute, Cary, North Carolina, USA) to estimate random intercept models with random effects for couples using the
Satterthwaite approximation for the denominator degrees of freedom. Dyadic data analysis uses the couple as the unit of analysis to directly model the interdependence of husbands’ and wives’ data (Kenny, Kashy, & Cook, 2006). Because we did not have hypotheses about differential effect of husband and wife, we did not test the full actor–partner interdependence model (APIM). Thus, following the approach recommended by Campbell and Kashy (2002, p. 331), our analyses utilized a simplified (i.e., nested) model such that husband and wife are nested within couple. The estimate of the couple-level variance component was statistically significant \(p < .05\), verifying the necessity for treating this with a multilevel model (using the dyad as the unit of analysis). Separate analyses were performed examining the impact of marital quality on pre- and postintervention levels of salivary \(\alpha\)-amylase, salivary cortisol, and ABP levels. For salivary OT concentration, all samples were obtained at home after the intervention or monitoring period had begun, thus we also examined the association between marital quality and levels during Week 1 and Week 4 of the intervention period. Analyses examining dependent variables (DV$s) at Time 1 (plasma OT and physiology) and Week 1 (salivary OT) included marital quality and covariates in the model. Analyses examining DV$s at Time 2 (plasma OT and physiology) and Week 4 (salivary OT) included marital quality, intervention condition (intervention and control), the statistical interaction between marital quality and intervention condition, and covariates in the model. Marital quality was treated continuously in the primary analyses and as a dichotomous variable in subsequent follow-up analyses. Gender and intervention condition were first centered at their grand mean before inclusion into the model. Because gender differences were found in ABP, gender was used as a covariate. Similarly, depression score as measured by the Center for Epidemiological Studies Depression Scale (Radloff, 1977) and stress score as measured by the Perceived Stress Scale (Cohen, Kamarck, & Mermelstein, 1983) were used as covariates in analyses involving OT concentration because they were found to be significant factors in these outcome measures (Holt-Lunstad, Birmingham, & Light, 2011). We compared the models with and without the covariates and in no cases did the inclusion of covariates significantly improve the model fit \(p > .05\). All analyses were two-tailed, and continuous data are reported as unstandardized regression coefficients.

**Results**

**Preliminary analyses**

We were interested in how our sample compared relative to others on the DAS and the extent of variability. The DAS scale range is 0–151, and in the validation sample (Spanier, 1976), the mean score overall was 101.5 and reported separate means for a married \((M = 114.8)\) and divorced \((M = 70.7)\) group. In comparison with the validation sample, our sample DAS scores range is 80–143 \((M = 112.53, SD = 15.44)\) suggesting that overall our sample appears somewhat well adjusted; however, there was variability in our sample. We found no significant gender difference for the DAS; however, despite randomization, we did find that there was a significant main effect of condition, \(F(1, 31) = 8.78, p < .01\), such that those in the intervention group had significantly higher DAS scores. Therefore, we repeated the analyses for our primary findings of the
intervention reported previously (Holt-Lunstad et al., 2008) while adjusting for relationship quality (DAS score). Each of the primary findings remained statistically significant. Thus, the effect of the intervention was independent of relationship quality.

The association between relationship quality and OT

Higher marital quality (defined prior to randomization) was significantly related to higher Time 1 plasma OT concentration obtained in the clinic, \( b = .18, t(38.1) = 3.55, p = .001 \). Although preintervention levels of plasma OT were within a similar range of values as postintervention and salivary levels, to ensure that findings were not being driven by a couple of high values (see plot in Figure 1) we repeated this analysis using the log-transformed values for preintervention plasma OT. The findings are consistent and significance was strengthened, \( b = .017, t(38.6) = 5.24, p < .0001 \).

Higher relationship quality also significantly predicted higher plasma OT concentration 4 weeks later, \( b = .12, t(44.2) = 1.80, p = .01 \). Similarly, when we examined salivary measures of OT concentration, we found that higher relationship quality significantly predicted higher salivary OT concentration obtained at home during both Week 1, \( b = .27, t(40.5) = 3.54, p = .001 \), and Week 4 of the intervention, \( b = .23, t(30.6) = 3.01, p = .005 \). We also examined whether the effect of relationship quality on OT concentration would be moderated by gender. There were no significant interaction effects between relationship quality and gender for any of the OT concentration measures (\( p > .10 \)).

The influence of relationship “distress”

Despite the overall association between higher relationship quality and OT, there remained the possibility that couples reporting more severe relationship distress might also have increased OT relative to nondistressed couples. To address this possibility we reanalyzed our OT concentration findings creating a categorical variable for relationship distress (DAS < 101.5) based on previously published clinical cutoffs for relationship distress (Spanier, 1976). Using this classification, 22 (32%) of our subjects would be classified as distressed. We found a significant effect of relationship distress on Time 1, \( F(1, 41) = 10.39, p = .003 \), and Time 2, \( F(1, 56) = 4.90, p = .03 \), plasma OT concentration, and a significant main effect for Week 1, \( F(1, 38.4) = 20.66, p < .0001 \), and Week 4, \( F(1, 50.9) = 7.02, p = .011 \), salivary OT concentration irrespective of intervention condition. In each case, relationship distress was associated with lower rather than higher OT concentration levels (see Table 1).

Some clinical research has further distinguished between those who are mildly distressed (DAS = 96–107) and those who are severely distressed (DAS < 80; Wood, Crane, Schaalje, & Law, 2005). Using these classifications, 26 (37.68%) of our subjects would be considered either mildly distressed or distressed (DAS ≤ 107), while none of our subjects would be considered severely distressed (DAS < 80). When we include those who are mildly distressed among our distressed classification and contrast them to those clearly not distressed (DAS > 107), we find a significant main effect for Time1, \( F(1, 43) = 11.92, p = .001 \), and Time 2, \( F(1, 59.7) = 8.20, p = .006 \), plasma OT
concentration as well as Week 1, $F(1, 38.9) = 20.10, p = .0001$, and Week 4, $F(1, 31) = 9.25, p = .005$, salivary OT concentration. In each case, higher relationship quality (not distress) was associated with higher OT concentration levels.

To further rule out the possibility that the association between relationship quality/distress might be a U-shaped relationship (which would be predicted if both extreme levels of support and distress were associated with high OT), we created a scatterplot of the raw data. As seen in Figure 2, the association between relationship quality (or the level of distress) appears linear across both plasma and salivary assessments of OT. Likewise, the general linear pattern holds regardless of intervention condition (see Figure 3). Therefore, we found no evidence that relationship distress was associated with elevated peripheral OT.

### The association between marital quality and physiology

Given the differential pattern of concurrent physiology found in previous research of relationship quality and OT, we also examined whether marital quality was related to stress hormones and ABP, again using gender as a covariate. For the five preintervention and five postintervention samples of $\alpha$-amylase and cortisol, area under the total response curve with respect to the ground was calculated using the trapezoid formula (Pruessner et al., 2003). Due to non-normal (skewed) distribution of the $\alpha$-amylase data,
Figure 2. Scatterplot of raw (unadjusted) data on the association between Dyadic Adjustment Scores (relationship quality) and Time 1 plasma OT ($r = .32; p < .01$) and Week 1 salivary OT ($r = .44; p < .001$). OT: oxytocin.
Figure 3. Scatterplot of raw (unadjusted) data on the association between Dyadic Adjustment Scores (relationship quality) and Time 2 plasma OT ($r = 0.36; p < 0.01$) and Week 4 salivary OT ($r = 0.47; p < 0.001$), according to intervention condition. OT: oxytocin.
this measure was log transformed prior to final data analysis. We found no significant main effect of marital quality for salivary measures of cortisol or α-amylase at Time 1 or Time 2 assessment \((p > .10)\). The effect of marital quality approached but did not reach significance for Time 1 24-h ambulatory SBP, \(b = .11, t(36.3) = 1.84, p = .07\), or DBP, \(b = .08, t(37.1) = 2.01, p = .06\). When we assessed the influence of marital quality on ABP a month later, the marginal effects were no longer evident.

**Does marital quality moderate the effect of the intervention?**

As reported in a previous publication, we found an effect of the intervention on physiology such that couples in the intervention condition had greater salivary OT and lower α-amylase relative to couples in the control condition (Holt-Lunstad et al., 2008). Likewise, males in the intervention condition showed significant decreases in ABP. Therefore, we next examined whether marital quality moderated the effect of the intervention. To do this, we looked at the statistical interaction between marital quality (treated continuously) and intervention condition at Time 2, controlling for gender and preintervention levels of each of our DVs (i.e., OT, stress hormones, and ABP). We found no significant interaction effect for any of the DVs \((p > .10)\). Instead, we observed independent effects of marital quality and the intervention for salivary OT concentration. Thus, the effectiveness of the intervention was not moderated by marital quality, and therefore, its benefits were not limited to couples who had either low or high marital quality.

**Discussion**

The primary aim of this study was to determine whether relationship quality is significantly associated with OT concentration and, if so, whether marital quality would moderate the influence of the couple support intervention. Our data suggest that higher relationship quality (not distress) in married couples is associated with higher plasma and salivary measures of OT and is predictive of OT levels 4 weeks later. These findings were consistent across both men and women and held constant when controlling for stress and depression levels. Marital quality, however, was not significantly related to BP or stress hormones (i.e., salivary cortisol and α-amylase) and did not moderate the influence of the support intervention.

**Relationship quality and OT concentration**

Although there is a great deal of research that links OT to social bonding in animals, little research has examined the influence of relationship quality on OT concentration in humans. Some recent evidence suggested that OT concentration may also be elevated in response to relational distress (Tabak et al., 2011); however, contrary to these studies, we found that better relationship adjustment (low distress) was associated with higher plasma and salivary OT concentration. Our data demonstrated that OT concentration levels were consistently lowest among the distressed group. This apparent inconsistency may be due to the fact that we controlled for stress and depression levels in our study, which have previously been found to be associated with increased OT levels.
As mentioned previously, OT activity is known to be stress responsive, as part of homeostatic regulation designed to reduce and shorten both adrenergic and HPA axis responses induced by stress. Controlling for this important factor may have allowed the positive effect of a supportive marital relationship on OT activity to be clearly revealed. Overall, our findings are consistent with the well-established role of OT in pair-bonding among monogamous animal species (Ross & Young, 2009; Smith, Agmo, Birnie, & French, 2010; Young, Gobrogge, Liu, & Wang, 2011) and some of the previous human research (Light et al., 2005; Schneiderman, Zagoory-Sharon, Leckman, & Feldman, 2012).

Our data appear reliable as our findings were consistent across both plasma and salivary measures and consistent across time. Higher relationship quality was not only associated with higher OT levels but higher relationship quality also significantly predicted higher OT levels a month later. Although both plasma and saliva was assayed identically, the consistency is remarkable, given that they were not assessed at the same time (pre- and postintervention vs. Week 1 and Week 4 during intervention) or the same context (lab vs. home), and the needle stick used to obtain plasma may have elicited a stress response that would not have likely occurred while obtaining a saliva sample. The positive association between relationship quality and OT found here also appears to be linear. The direction of the effects was always consistent, and no results were in the opposite direction. Thus, results in this study generally converge to illustrate positive effects of relationship quality on OT.

The present study underscores the importance of considering contextual factors in understanding the nature of OT and helps explain differences between our findings and other studies examining relationship distress. The context of studying OT sampling, the context of the relationship, and the way in which OT samples are processed may all potentially influence findings. For example, many studies of relational distress were conducted in the context of a laboratory stressor (Tabak et al., 2011; Smith et al., 2013), whereas our samples were collected in the context of warm social contact. Our study also differs in the relationship context itself, as many studies either assessed subjects not in a current romantic relationship (Gordon et al., 2008), or performed the assessments without their partner present as a participant (Tabak et al., 2011; Taylor et al., 2010) or their partner was in another room (Smith et al., 2013). Another possibility is that because subjects in our study knew that they were volunteering for an intervention study to improve their couple relationship, our subjects may have been more willing to report suboptimal relationship quality while those in other studies (e.g., Smith et al., 2013) may have been less candid about relationship problems. In our study OT concentration was assessed in both men and women, while most samples only assessed women (Tabak et al., 2011; Taylor et al., 2006). Likewise, our study simultaneously assessed both members of the pair-bond couple, and our analyses account for potential dyadic interdependence. We also used the recommended extraction step when assaying samples (Szeto et al., 2011), which may account for the inconsistency in OT concentration levels from studies that did not perform the extraction step. Our findings are consistent with others who found higher, and stable, plasma OT concentration among romantic relationships relative to those not in a romantic relationship (Schneiderman et al., 2012). Taken together, these data highlight the importance of considering the context when interpreting OT results.
Relationship quality and stress physiology
We had anticipated that relationship quality/distress would be associated with both stress hormones and ABP; however, we found no significant effect. Although we found marginal effects of relationship quality on ABP, these did not reach significance. Because our sample was young and healthy with relatively low BP, it is possible with a larger more diverse sample we may be able to better detect differences. Other research demonstrating elevations in OT concentration with relationship distress also found elevation in HPA axis activation including elevated cortisol. Given the context of sampling OT concentration was not a stressor, and OT concentration was not elevated with distress, it is perhaps not surprising that we do not see elevations in cortisol and α-amylase.

Intervention and relationship quality
Previously published data from this sample provides some evidence that it is possible to intervene to increase peripheral OT endogenously and that the intervention was also linked with decreases in BP and stress hormones. Importantly, the effect of the intervention on physiology was independent of relationship quality and vice versa. These data suggest that both stable and modifiable aspects of relationships are important to consider when understanding the influence of relationship quality on OT and physiology.

We also found no interaction between relationship quality and the intervention, suggesting that interventions need not be limited to subjects deemed to be high risk and rather individuals across the risk trajectory may show change. This is consistent with the evidence suggesting that protective influence of relationships may be a gradient rather than threshold effect (Holt-Lunstad et al., 2010). While such evidence is still preliminary, these may inform future research aimed at reducing health risk.

Potential limitations
Although we found no evidence of higher OT levels associated with relationship distress, and over 37% of our sample would be classified as either mildly or clinically distressed, we did not recruit for extreme distress. It is possible that extreme levels of distress may be associated with OT dysregulation similar to that seen among clinically depressed and anxious samples. However, it should be noted that other studies of relationship distress that showed findings opposite to ours (e.g., Taylor et al., 2010, and marginally significant trend for women only in the larger sample studied by Smith et al., 2013) also did not recruit clinically distressed individuals nor assess severe relationship distress. Therefore, future research is needed to further elucidate this association at extreme levels. Similar to other samples, our couples were also young and healthy, so it is unclear to what extent these results would generalize to older or clinical populations.

Despite the advantages of obtaining both plasma and salivary assessments of OT and obtaining these in different contexts (lab and home), because they were not assessed at
identical time points and contexts, this precludes direct comparisons between them. Nonetheless, despite these differences they were still significantly, albeit weakly, correlated (see Table 2). Further, we acknowledge that assessments of endogenous OT at each time point only involved one measurement; however, repeated measurements at each time point could account for the pulsatile release and short half-life of plasma OT secretion (Amico, Ulbrecht, & Robinson, 1987).

We also acknowledge that recently some assay methods have come under scrutiny (McCullough et al., 2013; Szeto et al., 2011); however, we used the recommended extraction procedures for EIA methods. Despite potential limitations, to date there is no superior assay method commercially available (McCullough et al., 2013). Likewise, others have failed to find detectable levels of OT in saliva (Horvat-Gordon, Granger, Schwartz, Nelson, & Kivlighan, 2005). However, these authors used a different extraction procedure and different assay than what was used in the current study. Recent studies utilizing the identical assay protocol used in this study have found that concurrent plasma and saliva OT concentration levels were significantly correlated with a moderately good degree of association in mothers of infants (Grewen, Davenport, & Light, 2010) and in nonvomiting anorexics (Hoffman, Brownley, Hamer, & Bulik, 2012). Further studies using the identical assay protocol used in this study found that salivary OT levels became significantly elevated after intranasal OT administration and remained elevated for more than 2½ (Huffmeijer et al., 2012) and 7 hr (van Ijzendoorn, Bhandari, van der Veen, Grewen, & Bakermans-Kranenburg, 2012) later relative to a group that received a placebo. Nonetheless, it is possible that such assays do not reflect OT in isolation and may be OT plus some other molecule; however, if so, this additional molecule is most likely either a longer precursor of OT (OT prepropeptide or OT intermediate peptide) or a partially metabolized, shorter protein that previously was OT (McCullough et al., 2013). Based on prior findings of an association between OT intermediate peptide and improved cardiovascular profiles (Light et al., 2005) both OT and related molecules may be useful markers of the extended OT system.

Table 2. Correlations between lab (plasma) and home (salivary) samples for endogenous oxytocin.

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<th></th>
<th>Plasma lab1</th>
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**Conclusions**

In conclusion, prior research has implicated OT as a possible pathway to explain the robust associations between social connectedness and long-term health and survival. This data provide potential clarification of the influence of relationship quality and suggest an independent association between OT concentrations and both stable and modifiable relationship factors.

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**Note**

1. The study by Smith and colleagues (2013) found that relationship quality was unrelated to plasma OT levels in men and showed a nonsignificant trend to be associated with lower rather than higher OT levels in women \( (r = -.13, p = .085) \). In this respect, their findings provide some support, albeit limited, for the hypothesis that elevated OT is linked to relationship distress.

**References**


