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More frequent partner hugs and higher oxytocin levels are linked to lower blood pressure and heart rate in premenopausal women

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Abstract

In animals, ventral stroking for >5 days increases oxytocin (OT) activity and decreases blood pressure (BP), but related human studies are few. Thus, relationships between self-reported frequency of partner hugs, plasma OT and BP levels were examined in 59 premenopausal women before and after warm contact with their husbands/partners ending with hugs. Higher baseline OT before partner contact was associated with lower BP and heart rate, and met criteria to be a partial mediator of the lower resting BP shown by women reporting more frequent hugs ($P < 0.05$). OT levels during post-contact stress were unrelated to hugs or BP. Menstrual cycle phase did not influence any OT measure. Thus, frequent hugs between spouses/partners are associated with lower BP and higher OT levels in premenopausal women; OT-mediated reduction in central adrenergic activity and peripheral effects of OT on the heart and vasculature are pathways to examine in future research.

Keywords: Oxytocin; Blood pressure; Partner support; Warm touch; Hugs

1. Introduction

Emotional support from a spouse or long-term partner is related to lower risk of cardiovascular and all-cause mortality (Berkman, 1995; Knox and Uvnas-Moberg, 1998; Kiecolt-Glaser and Newton, 2001; Tower et al., 2002). Blood pressure (BP) is especially sensitive to supportive and non-supportive interactions between partners (Ewart et al.,

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1991; Carels et al., 1998; Broadwell and Light, 1999; Gump et al., 2001; Grewen et al., 2003; Holt-Lunstad et al., 2003). Communication of emotional support is accomplished though multiple, complex modalities, including facial expression and body language as well as choice of words, emotional quality of speech, and listening/responding patterns that convey positive emotion and connectedness while couples interact, all of which may influence BP (Uchino et al., 1996; Denton et al., 2001; Gottman and Notarius, 2002; Broadwell and Light, 2004). Emotional support and affection in couples is also expressed through physical touch, such as hand-holding, hugs, and sitting or lying ‘‘cuddled up’’ (Diamond, 2000; Grewen et al., 2004a, 2004b).

A number of experts (Carter, 1998; Uvnas-Moberg, 1998, 2004; Insel and Young, 2001; Taylor, 2002; Moyer et al., 2004) have hypothesized that enhanced oxytocin (OT) activity is a logical candidate to be one of the primary physiological mediators of the health benefits of emotional support, particularly those linked to warm touch. Although best known for its role in parturition, breast-feeding and initiation of maternal behavior, OT is a hypothalamic neuropeptide shown in animal models to be critically involved in important social behaviors including social recognition, partner preference and, in certain species, monogamous pair-bonding (Williams et al., 1994; Pedersen, 1997; Carter et al., 2001; Ferguson et al., 2002; Pedersen and Boccia, 2002; Bales and Carter, 2003; Champagne et al., 2003; Choleris et al., 2003). Furthermore, increases in endogenous OT activity are elicited by massagelike stroking in both infant and adult mammals (Uvnas-Moberg, 1998, 2004), although recent work by Lund et al. (2002) confirmed that increases in plasma levels of OT in rats reflect the cumulative effect of repeated episodes of stroking. In their study, plasma OT increases were significant after 14 days but not after 3 days of such stroking.

OT has both central and peripheral actions on cardiovascular function (Petersson et al., 1996; Gutkowska et al., 2000; Petersson, 2002). Although a single dose of OT in rats leads to BP increases, not decreases, daily OT administration (or massagelike stroking to enhance endogenous OT activity) for 5–14 days leads to enduring BP reductions that far outlast the intervention (Petersson et al., 1999; Holst et al., 2002). Enhanced OT activity of this kind leads to inhibition of central and peripheral alpha-adrenergic and hypothalamic-pituitary-adrenal (HPA) activity, while promoting parasympathetic cardiac control (Diaz-Cabale et al., 2000; Janowski et al., 2000; Mukaddam-Daher et al., 2001). Co-localized estrogen and OT receptors influence each other, such that OT activity can have greater cardiovascular effects in cycling vs. ovariectomized females or males (Petersson et al., 1999; Holst et al., 2002).

Despite the extensive literature on OT in animal models, relatively few published studies on human OT responses exist to date. This paucity of findings is due in part to the fact that, unlike animal research that can assess OT mRNA or use central administration of OT antagonists, in humans, researchers must rely upon less direct measures to index oxytocinergic activity: plasma levels of OT and OT-precursor peptides. These peptide levels in humans appear to reflect both general oxytocinergic activity levels of the past weeks, such as increases in OT intermediate peptide seen in post-menopausal women on estrogen replacement (Crowley et al., 1995; Amico and Hempel, 1990; Bossmar et al., 1995; Light et al., 2004b), as well as immediate powerful stimuli in the past few minutes. In fact, there have been few demonstrations of an acute stimulus (other than breast stimulation or nursing in post-partum women) that elicits a consistent increase in plasma OT, or a personal characteristic (such as maternal attachment for her infant, or spouse/partner relationship quality) that is linked to higher overall plasma levels of OT. Single episodes of massage have been shown to elicit increases in plasma OT levels in some individuals but not consistently enough to yield reliable group effects (Turner et al., 1999; Wikstrom et al., 2003). However, given the findings of Lund et al. (2002) on the need for many days of massage repetitions to elicit increases in plasma OT in animals, this inconsistent effect of a single episode of massage on human plasma OT levels is not surprising.

In an initial study of effects of warm contact with loved ones on OT, Light et al. (2000) studied OT and BP responses before and during a speech task in 24 mothers of infants on 2 days, once after holding their babies and once after a control rest alone. BP levels were lower on both test days before, during and after the speech task in mothers whose OT levels increased versus decreased over baseline levels in samples obtained 5 min after baby holding (during the task). The OT increase group did not show a reliable OT increase to the speech task when tested without their babies, so the prior warm contact was critical in eliciting an OT response. An extension of this work comparing responses of these healthy mothers with mothers who had been exposed to cocaine during pregnancy (Light et al., 2004a) confirmed that the cocaine exposed group had lower OT levels and higher BP and norepinephrine (NE) levels both in the lab on the no baby contact day and during ambulatory monitoring at home. The cocaine exposed mothers also showed a tendency to hold their babies less often at home. In rats, cocaine exposure during pregnancy disrupts normal post-partum OT activity and maternal behavior (Elliott et al., 2001). These findings link greater mother–infant warm contact time to higher OT activity and lower BP in post-partum women.

Next, we examined OT response and resting BP in 38 couples before, during and after a 10 min period of warm partner contact ending with a 20 s hug (Grewen et al., 2004a, 2004b). In this study, which involved no stressors, both men and women with more supportive partners showed higher levels of plasma OT before, during and after the warm contact period. Women (but not men) with greater partner support showed lower baseline SBP and plasma NE levels, and OT met criteria as significant mediator of the reduced NE levels (but not the lower BP) in these women. Grewen et al. (2004a, 2004b) also reported on a pilot study involving 11 subjects retested four different times, during both rest and stress sessions, both with and without partner contact. OT responses were higher during rest vs. stress sessions with warm partner contact.

Thus, in the present protocol where partner contact preceded a speech stressor, we elected to focus on plasma OT levels of premenopausal women during baseline prior to warm partner contact rather than on OT responses during the stressor, and to determine whether women with higher OT levels had lower BP and HR: (1) during a resting baseline period just prior to warm partner contact, and (2) during a speech task that followed warm contact. We further examined whether greater self-reported frequency of one type of warm touch between partners, Partner Hugs, predicted lower BP and HR during baseline and/or stress events. Finally we attempted to test whether OT activity (indexed by plasma levels) may be a partial mediator of the expected relationships between greater Partner Hugs and lower cardiovascular responses. As a methodological issue, we also examined whether plasma OT levels differ by menstrual cycle phase, to determine if cycle phase must be controlled in this and future research on OT.

2. Methods

Premenopausal women aged 20–49-years old ($n = 59$) were recruited using local newspaper advertisements and fliers. Subjects were required to be living with current spouse or monogamous partner for at least 6 months; these partners participated with the women in our study by providing them with 10 min of warm physical and emotional contact during the testing session. Reasons for exclusion included current use of prescription medication affecting the cardiovascular and autonomic nervous system, chronic systemic disease, current clinical depression or other psychiatric disorder, pregnancy, breast-feeding, post-menopausal status, or being less than 11 months post-partum. The protocol was approved by the local IRB and all subjects and their partners signed approved consent forms before participating.

Women were subgrouped into three groups based on the magnitude of their OT levels at baseline. Those in the top, middle and bottom tertiles made up the high, moderate and low OT groups, respectively. Table 1 gives demographic information for these groups. The low OT group showed weak trends toward younger age, higher BMI, and greater percentage on non-white members compared to the high OT group, but these differences were not significant. Surprisingly, a significantly greater percentage of this low OT group were married versus living with long-term partners compared to the other groups ($\chi^2(2) = 6.86$, $P < 0.033$). Although the low OT group included more women who had never been pregnant or borne a child (Nulliparous: 42% versus 13% and 20%), this difference was not significant ($\chi^2(2) = 4.33$, $P < 0.20$).

2.1. Test session procedures

Subjects were first screened during a brief telephone interview. Partners arrived together but were immediately separated. Each woman was instrumented with the Accutracker II BP monitor and an intravenous (i.v.) catheter for blood sampling. A 20 min period for instrumentation/adaptation was followed by solitary resting baseline (10 min). Subjects then joined their partners in a different room for the warm contact period (10 min), and were separated again for the stressor events (10 min). *Baseline period*: As described above, women were seated alone in comfortable chairs in a room separated from their partners. BP and HR data sampled at 4, 6 and 8 min was averaged to represent baseline levels. Blood was drawn starting at 8 min of baseline for OT. *Warm contact period*: Couples were seated on a loveseat in a quiet room and instructed to sit close together, holding hands if they felt comfortable doing so. They were asked to talk about a time they had spent together that had made them feel closer as a couple (2 min). Next they watched a 5 min segment of a

Table 1
Demographic data for high, moderate and low OT groups

OT group	*N*	Age	BMI	Non-white (%)	Married (%)	Nulliparous (%)
High	15	30.5 ± 2.4	25.3 ± 1.7	20	53	13
Moderate	25	29.1 ± 1.3	27.3 ± 1.4	24	56	20
Low	19	27.5 ± 1.1	31.2 ± 2.3	58	89*	42

* $P < 0.05$.

romantic video they had previously seen. They then were instructed to talk again for 2 min about a time during which they felt especially close as a couple. During this time couples were left alone for privacy, unmonitored and unobserved except when the experimenter entered the room to give instructions. At the end of this session partners stood for a 20 s hug. *Post-contact stressor*: Women were immediately separated from their partners to undergo stressor testing modeled after the methods of Light et al. (2000). Briefly, the stressor first involved 2 min of task instructions, followed by three components: (1) silent speech preparation (2 min), (2) actively giving a tape-recorded speech about a recent interpersonal event (one not involving their partners) that made the woman feel angry or stressed (3 min), and (3) post-speech recovery while listening to a replay of their own tape-recorded speech (3 min). BP and HR were measured once during preparation, twice during active speech and twice during recovery, with 1 min intervals separating each reading; the two readings for each of the latter events were averaged. Additional blood samples for OT were drawn during speech preparation, active speech and post-speech recovery.

2.2. Cardiovascular assessment

Subjects were instrumented with the Accutracker II ambulatory BP monitor (Suntech, Raleigh, NC), a device whose prototype has been validated against direct arterial and standard auscultatory measurements (Light et al., 1988). In order to standardize the Accutracker readings to clinic BP assessments, a minimum of three seated BP readings were then taken with the Accutracker monitor, while simultaneous auscultatory BP readings were assessed by a trained technician. Monitor readings for systolic (SBP) and diastolic (DBP) BP falling within 5 mmHg of the stethoscopic values were considered acceptable, provided the Accutracker displayed no error codes. Heart rate (HR) levels were determined from the Accutracker ECG leads and mean arterial pressure (MAP) was calculated automatically by the formula (SBP − DBP)/3 + DBP.

2.3. Plasma OT measures

Blood was sampled four times for determination of plasma OT levels: (1) immediately before the end of the 10 min solitary baseline, just prior to the period of warm partner contact, (2) at the midpoint of speech preparation, (3) at the midpoint of the active speech, and (4) during speech recovery. The level of OT in EDTA plasma was determined by extraction and radioimmunoassay in the Laboratory of Janet Amico (Amico et al., 1981; Amico and Hempel, 1990). The intra-assay coefficient of variation was 10–12% and the low limit of sensitivity was 0.5 pg/ml; plasma OT values of these women ranged from 0.5 to 4.8 pg/ml. Preliminary analyses determined that OT levels were not normally distributed, and thus, in all subsequent analyses, OT measures first underwent square-root transformation to achieve greater normality of distribution.

For analyses in which OT groups were compared, the transformed baseline OT cut-points defining the three OT groups were: low OT group < 0.89 (mean = 0.79), high group OT > 1.09 (mean = 1.23), and moderate OT group = 0.89–1.09 pg/ml (mean = 0.98) (n = 19, 15 and 25, respectively; group sizes differ from true tertile split of all n = 19 and 20 owing to ties at cut-points). Although defined based on their OT levels at baseline, ANCOVA with age as a covariate confirmed that the high OT and low OT groups differed reliably in their square-root transformed OT levels across all sampling periods except active speech (baseline: 1.23 versus 0.79, $P < 0.0001$; speech preparation: 1.07 versus 0.88, $P < 0.008$; active speech: 1.03 versus 0.97, $P > 0.50$; recovery: 1.11 versus 0.91, $P < 0.006$).

2.4. Relationship quality questionnaires

Subjects completed two questionnaires. The first was a five-item modified version of the Physical Affection Scale (PAS) (Diamond, 2000) assessing the frequency that they typically do the following with their partners: hold hands, sit close or lie down close together, give each other neck or back massages or similar warm touches, hug, or kiss. The six response choices ranged from "never or almost never" to "more than once a day". Based on the animal literature that multiple days of ventral stroking elicits plasma OT increases, we hypothesized that two items, the frequency of massage/warm touch and the frequency of hugging (ventral contact) would show the strongest relationships to increased OT activity. Because the partner contact condition of our protocol ended with a 20 s hug (but did not include any massage component), we elected to use frequency of Partner Hugs as the most directly relevant index of individual differences in habitual warm physical contact between partners.

Subjects also completed the spousal version of the five-item Social Relationships Index (SRI), developed as a brief self-report version of the social support interview (Uchino et al., 1992, 1996; Holt-Lunstad et al., 2003), to assess general emotional support from the partner. Items ask the subject to rate both the positive (love and closeness) and the negative (upsetting, mixed or conflicted feelings) emotional components of their partner relationships.

2.5. Statistical methods

Preliminary analyses were performed to examine whether plasma OT levels differed by menstrual phase at time of testing. Women were subgrouped based on days since the onset of their last menstrual period as follows: (1) follicular: days 1–12 ($n = 11$), (2) midcycle: days 13–18 ($n = 11$), and (3) luteal: days 19–34 ($n = 13$). Oral contraceptive users ($n = 17$), tested while actively taking their pills, were grouped separately, while the small group of women ($n = 4$) reporting long and/or irregular cycles exceeding 34 days were excluded from these comparisons. No differences in plasma OT levels were seen among the women in the follicular, midcycle, luteal phase and oral contraceptive groups at any of the our sampling times (main effect of menstrual phase $F(3,50) = 1.17$, $P > 0.30$ and menstrual phase × time period interaction $F(12,150) = 0.86$, $P > 0.50$). In fact, mean plasma OT levels of all four groups were so similar at baseline (1.09, 0.91, 0.93 and 0.91 mg/dl for follicular, midcycle, luteal and oral contraceptive groups, respectively), they support the interpretation that menstrual cycle phase variations in OT levels in premenopausal women are small and might be easily masked by other influences.

Primary analyses took two forms. First, mean SBP, DBP, MAP and HR levels during four time periods (baseline, speech preparation, active speech and recovery) were compared among the high, moderate and low OT groups in a repeated-measures MANCOVA with age as covariate. Independent *t*-tests using age-adjusted means were used to clarify which specific groups differed significantly from each other in these dependent measures. Second, partial regression analyses adjusting for age were used to examine relationships of Partner Hugs to OT, BP and HR measures during all four time periods listed above. For those instances where Partner Hugs predicted both age-adjusted OT and cardiovascular responses, mediational analyses using the approach recommended by Baron and Kenny (1986) were used to test whether the effect of Partner Hugs was partially mediated by OT. Unless other specified, alpha level was $P < 0.05$ two-tailed.

3. Results

3.1. Cardiovascular responses of high, moderate and low OT groups

Cardiovascular responses of women grouped by their baseline OT levels were found to differ as predicted, but these differences were significant only at baseline. Repeated measures age-adjusted MANCOVAs yielded a significant interaction of OT group × time period for SBP and DBP ($F(6,102) = 2.20$ and 2.19, respectively, $P \leq 0.05$). To clarify this interaction, we compared group responses at each time period separately with ANCOVA, and obtained a significant effect of OT group at baseline only for SBP and MAP ($F(2,55) = 5.35$ and 3.57, $P < 0.0075$ and 0.035, respectively). Subsequent mean comparisons confirmed that the low OT group had significantly higher SBP, DBP and MAP at baseline than the high OT group (least-square comparisons among age-adjusted means, $P < 0.0023$, 0.04, and 0.01, respectively; see Figs. 1–3). Also, the low OT group had significantly higher baseline SBP than the moderate OT group ($P < 0.032$). During the three stressor periods (speech preparation, active speech and post-speech recovery), the OT groups no longer differed significantly in any BP or HR measure (all $P > 0.10$), although there was a tendency for the High OT group to maintain the lowest mean BP levels across events (see Figs. 1–3). OT group differences in baseline HR were also seen ($F(2,55) = 3.73$, $P < 0.033$; not depicted). Similar to SBP, the low OT group had significantly higher baseline HR than the high OT or the moderate OT groups (age-adjusted least-square means ± S.E. = 80.3 ± 3.1 versus 68.5 ± 3.3 and 71.8 ± 2.7 beats/min, $P < 0.014$ and 0.043, respectively).

3.2. Frequency of hugs from partner: links to OT and cardiovascular responses

As predicted, partial correlation coefficients (adjusted for age) indicated that greater frequency of Partner Hugs and of Partner Massages were associated with higher baseline OT level ($r = +0.31$ and +0.29, $P \leq 0.02$ and 0.03, respectively); other PAS items (kissing, hand-holding, sitting/lying close) were not reliably correlated with any OT measure. Interestingly, greater frequency of Partner Hugs was related to having fewer children at home (range zero to four children; $r = -0.32$, $P < 0.02$). However, consistent with the link between OT and maternal behavior, caring for more children at home was associated with

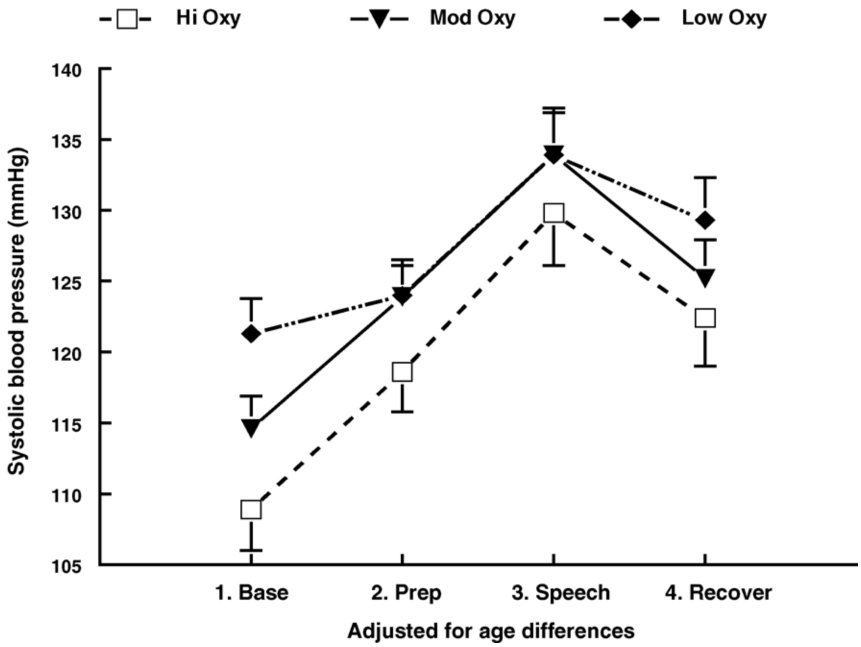

Fig. 1. Systolic BP levels in the high OT (open squares), moderate OT (filled triangles) and low OT groups (filled diamonds) during baseline (Base) prior to partner contact, and the three post-contact periods: speech preparation (Prep), active speech (Speech) and post-speech replay/recovery (Recover). Low OT group > high OT and moderate OT groups at Base, $P < 0.0023$ and 0.032, respectively.

higher baseline OT, after partialing out the effect associated with Partner Hugs (partial $r = +0.32$, $P < 0.04$).

Subsequent analyses focused exclusively on greater Partner Hugs as a potential predictor of increased OT and decreased cardiovascular responses. Frequency of hugs was correlated moderately but did not show extensive overlap with partner support (defined by SRI score; $r = +0.49$, $P < 0.0001$), and in this sample, unlike the women and men studied by Grewen et al. (2004a, 2004b), higher SRI score was not significantly associated with higher baseline OT level. Consistent with a priori hypotheses, women reporting more frequent Partner Hugs had lower baseline BP levels ($r = -0.29$, -0.34 and -0.33, $P \leq 0.032$ for SBP, DBP and MAP, respectively). Greater Partner Hugs also predicted lower HR levels during speech preparation and active speech ($r = -0.35$ and -0.33, $P \leq 0.04$, respectively), but not during baseline ($r = -0.20$, $P > 0.20$) or recovery ($r = +0.02$, $P > 0.90$). Partner Hugs showed a marginally significant relationship to DBP during speech preparation ($r = -0.23$, $P < 0.10$) but did not significantly predict any other BP measure during the speech preparation, active speech or post-speech recovery ($r = -0.12$ to -0.17 during preparation, $r = -0.05$ to -0.10 during active speech, and $r = -0.05$ to $+0.04$ during recovery, respectively).

Higher baseline OT was significantly correlated with lower age-adjusted SBP, DBP, MAP and HR at baseline ($r = -0.39$, -0.32, -0.36 and -0.42, $P \leq 0.003$, 0.016, 0.006

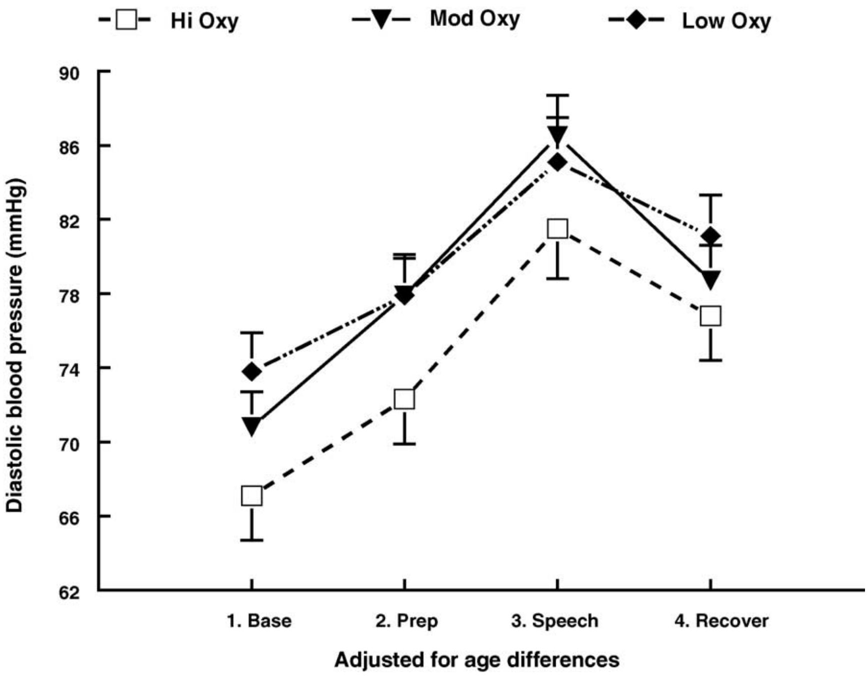

Fig. 2. Diastolic BP levels in the high OT, moderate OT and low OT groups, depicted as described in Fig. 1. Low OT group > high OT group at Base, $P < 0.04$.

and 0.007, respectively) and at least marginally related to all cardiovascular measures during speech preparation ($r = -0.23$, -0.27, -0.28 and -0.27, $P \leq 0.09$, 0.04, 0.04 and 0.10, respectively) and to all BP measures during recovery ($r = -0.24$, -0.22, -0.24, $P \leq 0.08$, 0.10 and 0.08, respectively), but unrelated to the cardiovascular measures during active speech ($r = -0.14$ to -0.20, $P > 0.13$). In contrast, OT levels from the other three time periods surrounding the stressor were consistently unrelated to any cardiovascular measure ($r = -0.07$ to -0.21 for speech preparation OT, $P > 0.10$; $r = +0.04$ to -0.11 for active speech OT, $P > 0.40$, and $r = +0.06$ to -0.08 for recovery OT, $P > 0.50$). Likewise, Partner Hugs was consistently unrelated to OT levels obtained during speech preparation, active speech or recovery ($r = +0.06$, +0.07 and +0.08, $P > 0.50$). Thus, only baseline OT was a potential candidate as a mediator of the Partner Hugs link to lower BP.

Subsequently, a series of linear regression analyses was performed to test whether the effect of Partner Hugs on age-adjusted baseline BP measures and on DBP and HR during preparation might be mediated by baseline OT, as per the method described by Baron and Kenny (1986). Evidence of mediation would be provided only if (1) greater frequency of Partner Hugs was related to lower BP or HR, (2) higher plasma OT at baseline was related to greater Partner Hugs and also, as previously demonstrated, to lower BP or HR, and (3) the addition of baseline OT into the model reduced the regression coefficient of Hugs as predictor of baseline SBP, DBP, MAP or of preparation or speech HR levels. Results of these regression analyses, shown in Table 2, reveal that all of these statistical conditions

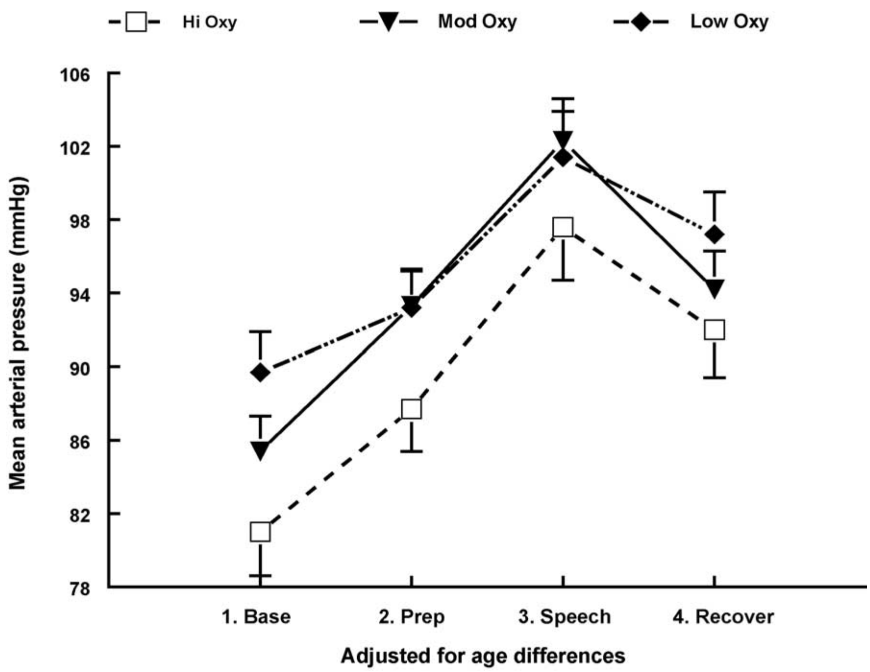

Fig. 3. Mean arterial BP levels in the high OT, moderate OT and low OT groups, depicted as described in Fig. 1. Low OT group > high OT group at Base, $P < 0.01$.

were met for baseline OT serving as a significant partial mediator of the effect of Partner Hugs on baseline SBP and MAP in these premenopausal women (all $P < 0.05$), as well as a marginally significant mediator of the effect of Partner Hugs on baseline DBP and speech preparation DBP ($P < 0.067$ and 0.09). During speech preparation (depicted) and during active speech (latter not depicted in Table 2), although greater Partner Hugs was related to lower HR levels, baseline OT was too weakly related to HR to meet criteria as a partial mediator of these relationships.

4. Discussion

This novel translational study in premenopausal women confirmed that higher baseline OT levels were linked to lower BP and HR levels, and that a history of more frequent Partner Hugs was associated with higher baseline OT and lower cardiovascular responses. The observed baseline OT and BP differences may reflect the combined effects of the individual's general state of oxytocinergic activity, her anticipation of the upcoming partner contact, and her prior experience in regard to warm contact with her partner. In contrast, OT levels obtained during speech preparation, active speech, and post-speech recovery were unrelated to cardiovascular responses, Partner Hugs, or baseline OT. Other investigations by Altemus et al. (2001a), Turner et al. (2002) and Bonfiglio and Stoney

Table 2
Mediational analyses: effect of Partner Hugs on cardiovascular measures is partially mediated by baseline (Base) plasma oxytocin (OT)

Models 1–6b (CRITERION/Predictor)	t	b	β	Full model (R^2)
(1) BASE OT				
Partner Hugs	2.39*	0.04	0.302	0.09
(2a) BASE SBP				
Partner Hugs	−2.24**	−2.58	−0.279	0.13
(2b) BASE SBP				
Base OT	−2.54*	−20.73	−0.321	
Partner Hugs	−1.46	−1.68	−0.182	0.22
(3a) BASE DBP				
Partner Hugs	−2.68**	−2.39	−0.313	0.23
(3b) BASE DBP				
Base OT	−1.86+	−12.03	−0.225	
Partner Hugs	−2.04*	−1.87	−0.245	0.28
(4a) BASE MAP				
Partner Hugs	−2.64**	−2.45	−0.314	0.21
(4b) BASE MAP				
Base OT	−2.24*	−14.93	−0.274	
Partner Hugs	−1.92+	−1.81	−0.232	0.27
(5a) PREP DBP				
Partner Hugs	−1.71+	−1.63	−0.22	0.12
(5b) PREP DBP				
Base OT	−1.65+	−11.43	−0.22	
Partner Hugs	−1.14	−1.13	−0.15	0.16
(6a) PREP HR				
Partner Hugs	−2.27*	−4.07	−0.35	0.12
(6b) PREP HR				
Base OT	−1.33	−15.36	−0.21	
Partner Hugs	−2.00+	−3.61	−0.31	0.16

+ $P < 0.10$.
* $P < 0.05$.
** $P < 0.01$.

(2004) likewise failed to obtain expected increases in plasma OT during stress or emotional stimuli. OT is known to be stress-sensitive, but consistent with findings by Sanders et al. (1991), we hypothesize that persons who experience a more pronounced sympathetic and/or HPA response during stress are more likely to show greater OT increases during stress; we would expect these subjects to show higher, not lower, BP and HR. However, higher baseline OT was correlated with lower BP during post-contact speech preparation and correlated marginally with lower BP during speech recovery, though not during active speech. This supports our earlier interpretation (Light et al., 2000) that women with greater OT activity show a more efficient, time-limited stress response, not a reduction in peak stress responses.

The association between greater self-reported frequency of Partner Hugs and lower BP during baseline before partner contact, and its potential mediation by higher OT, are observations in humans similar to those in rats showing that repeated daily stroking induces plasma OT increases and BP decreases (Lund et al., 2002; Holst et al., 2002). Interestingly, mothers with more children at home also had higher baseline OT levels, after partialing out effects of Partner Hugs, which was inversely related to number of children at home. The association between few or no children and high Partner Hugs may be due to the ‘‘honeymoon effect’’ early in a marital or partner relationship that normally precedes parenthood. The link between more children at home and higher baseline OT is consistent with the animal literature linking higher OT activity to greater maternal behavior (Pedersen, 1997; Pedersen and Boccia, 2002).

Baseline OT met all criteria to be a partial mediator of the lower baseline SBP and MAP associated with greater Partner Hugs, and was marginally significant as a mediator for baseline and speech preparation DBP as well. The reduction in BP linked to OT might be due to decreased central alpha-adrenergic activity, or to direct peripheral effects of circulating OT on the heart and vasculature (Petersson, 2002). Despite meeting statistical criteria as a mediator, it must be emphasized that all of the relationships are regression-based (correlational), and thus this type of cause–effect role for OT remains hypothetical in humans. A plausible alternative explanation is that some other yet unidentified factor (behavioral or biological) correlated with all of these measures is the true mediator. Other potential factors that might be associated with greater hugs and OT and with reduced BP and HR prior to partner contact include personality factors (e.g., affectionate nature, low hostility), experiential factors (past history of consistently loving and supportive interactions with partner and other loved ones, or modeling of positive partner interactions by ones’ own parents), and biological factors (greater chronic estrogenic or other reproductive hormonal activity, or enhanced dopaminergic activity).

In our previous study by Grewen et al. (2004a, 2004b) using a protocol involving partner contact followed by solitary rest, baseline OT met criteria as a mediator of the relationship between greater partner support and lower plasma norepinephrine in women, which would be explained equally well by either the central or peripheral OT effect. In that protocol, however, OT did not appear to mediate the relationship between greater partner support and lower BP in those women (Grewen et al., 2004a, 2004b). One possible explanation for this difference between studies is that OT activity may be more readily evoked by warm touch and physical expressions of affection and support between partners, like hugs, and is only indirectly linked to other less physical ways of conveying support. It is noteworthy that another form of physical affection, frequency of neck or back massages between partners, was also related to higher OT levels. An alternative explanation is that the sample size in the present study was larger, and therefore the present study had more power to detect a mediational effect. Other protocol differences, such as knowledge of the upcoming task, may also be factors.

Greater Partner Hugs also predicted lower HR during speech preparation and active speech, but the HR reduction did not appear to be due to OT. Our prior research indicated that OT is a significant mediator of differences in sympathetic nervous system activity, reflected in lower plasma NE levels (Grewen et al., 2004a, 2004b). This is also consistent with studies documenting that long term increases in OT activity in rats leads to decreases in central alpha-adrenergic tone, and this is the source of the sustained BP decreases that result (Diaz-Cabale et al., 2000; Petersson, 2002). Lower HR levels during speech preparation and active speech associated with greater Partner Hugs may instead be due to increases in parasympathetic activity.

Although the present report was restricted to premenopausal women, it is worthwhile to integrate the present findings with other reports focused on gender and reproductive/hormonal status differences in OT activity. Men as well as women have OT activity, known to play a role in male sexual arousal and orgasm (Carter et al., 1995; Barbaris and Tribollet, 1996); in monogamous species like prairie voles, it also enhances pair-bonding and mate-guarding (territoriality) (Williams et al., 1994; Bales and Carter, 2003). In our prior study of couples, although plasma OT levels were higher in both men and women with high versus low partner support, men did not show the OT increase 7 min after warm partner contact or the link between higher OT and lower sympathetic nervous system activity that women showed (Grewen et al., 2004a, 2004b). Because of OTs role in the initiation of maternal behavior (one of the imperatives of survival for mammalian species), it is logical in an evolutionary sense that reproductive-age females might have the potential for greater and more broadly influential OT activity (Insel and Young, 2001; Taylor, 2002; Champagne et al., 2003). Genetic knockout mouse models have confirmed that estrogen and OT receptors co-localized in the paraventricular and supraoptic nuclei of the hypothalamus and in the amygdala modulate each other, and that female mice lacking either the estrogen or the OT receptors demonstrate similarly impaired social behavior (Choleris et al., 2003). As infants, these OT knock-out mice vocalize less during separations from their dams, eliciting less licking and other maternal behavior when separation ends, while as adults, the females show less maternal behavior and the males show increased aggression (Winslow et al., 2000; Mantella et al., 2003; Choleris et al., 2003).

Our study obtained no differences in plasma OT measures in normally cycling women tested during the follicular, mid-cycle or luteal menstrual phases, and no differences between such women and others tested on oral contraceptives. Although we did not confirm self-reported cycle phase with estradiol, progesterone or luteinizing hormone measures, our findings are consistent with prior reports by Steinwall et al. (1998) and Altemus et al. (2001a, 2001b); Steinwall et al. (1998, p. 983) conclude that, although its sister nonapeptide, vasopressin, does vary over the menstrual cycle, ‘‘the influence of ovarian hormones on OT secretion is minimal’’ in non-pregnant, normally cycling women. Nevertheless, even though plasma OT does not vary consistently across the menstrual cycle, OT activity (as assessed by OT mRNA) does vary in both hypothalamic and uterine tissues (Amico et al., 2000; Steinwall et al., 2004). This serves as a reminder that plasma OT level does not consistently mirror OT activity within the central nervous system, especially subtle increases or decreases.

These findings encourage further study in humans of the effects of long-term or multiple repeated episodes of warm touch, with OT and cardiovascular responses included among the outcome measures. Previous studies have shown that ambulatory BP is lower when men and women are with their partners than with other individuals, and that this effect is greater if the partner relationship is more supportive and less ambivalent (Gump et al., 2001; Baker et al., 2003; Holt-Lunstad et al., 2003). It would be fascinating to employ a more direct intervention approach to assess whether OT may be a potential mediator of these BP benefits. In addition to couple studies, further research is encouraged on the importance of warm touch in mother–infant and father–infant bonding, and the possible involvement of OT activity to these important familial ties. Finally, other important long-term relationships (friendships, homosexual partner relationships, even pets) may be usefully studied with a similar approach (Uchino et al., 1996; Diamond, 2000; Allen et al., 2002; Odendaal and Meintjes, 2003).

5. Summary

Among 59 premenopausal women tested in the context of a 10 min period of warm physical and emotional contact with their partners, those women showing higher plasma OT levels just prior to the contact period had lower pre-contact resting BP and HR. Higher pre-contact OT level was also related to lower BP during preparation for and recovery after a stressful speech task, though these relationships were in some cases only marginally significant. Women who reported greater frequency of hugs with their partners were found to have lower baseline BP as well, and OT was determined statistically to meet criteria as a potential mediator of these effects. These findings encourage further research into the relationships of physical and/or emotional support, OT, and cardiovascular or other health-relevant measures, especially within the context of the family.

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