Psychoneuroendocrinology (2007) 32, 565–574

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Effects of different kinds of couple interaction on cortisol and heart rate responses to stress in women

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Received 15 November 2006; received in revised form 7 March 2007; accepted 17 March 2007

KEYWORDS
Social support;
Stress;
Physical contact;
Cortisol;
Heart rate;
Oxytocin

Summary
In animal studies, positive social interaction and physical contact play a preeminent role in the control of behavioral and neuroendocrine responses to stress. The aim of this study was to determine whether specific kinds of couple interaction reduce hypothalamic–pituitary–adrenal (HPA) and autonomic responses to psychosocial stress in women. Sixty-seven women, aged 20–37 years, who had been married or cohabiting with a male partner for at least 12 months at the time of the study, were exposed to a standardized psychosocial laboratory stressor (Trier Social Stress Test). Participants were randomly assigned to three study groups differing in the type of a 10-min period of social interaction with their partner prior to stress: $n = 25$ with no partner interaction, $n = 22$ with verbal social support, and $n = 20$ with physical contact (standardized neck and shoulder massage). Salivary free cortisol levels, plasma levels of oxytocin, heart rate, and psychological responses to stress were compared among the three study groups.
Women with positive physical partner contact before stress exhibited significantly lower cortisol and heart rate responses to stress but no different plasma oxytocin levels compared to women who received social support or no social interaction. Verbal social

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0306-4530/$ - see front matter
doi:10.1016/j.psyneuen.2007.03.011

support alone was not associated with reduced stress responsiveness. Our results are in line with previous human studies indicating reduced responsiveness to verbal social support by a spouse in women. More importantly, these findings imply a direct protective effect of touch on stress-related neurobiological systems as a possible underlying mechanism of health beneficial effects of positive couple interaction.

1. Introduction

A growing body of epidemiological research in clinical populations has provided support for the hypothesis that social support improves outcome or recovery following many types of human diseases (Broadhead et al., 1983; House et al., 1988; Uchino et al., 1996; Seeman, 2000; Cohen, 2004). Conversely, low levels of social support are associated with impaired mental and physical health, such as cardiovascular diseases, depression, and attenuated immune function (Cohen et al., 1997; Welin et al., 2000; Cacioppo et al., 2002). In particular, being married or cohabiting with a significant other appears to be one of the most powerful sources of support in humans (Burman and Margolin, 1992). Numerous studies show that married individuals have lower rates of morbidity and mortality compared with non-married individuals. Interestingly, marital status has been found to afford greater protection for men than women (Case et al., 1992; Williams et al., 1992; Johnson et al., 2000; Kiecolt-Glaser and Newton, 2001), and women appear to be particularly susceptible to the health disadvantages associated with marital stress (Coyne et al., 2001), including higher risk for coronary heart disease related to marital as compared to work stress (Orth-Gomer et al., 2000). However, it has not been investigated experimentally whether there are specific kinds of couple interaction that might be beneficial in women.

Despite the considerable knowledge from epidemiological studies concerning the health-promoting effects of social support in general, and of couple interaction in particular, the underlying physiological mechanisms are yet to be determined. In animal research, affiliative social behavior has been shown to exert behavioral and physiological stress-attenuating effects (Carter, 1998; Lonstein, 2005; Bartz and Hollander, 2006; Gunnar and Quevedo, 2006). In addition, positive social interaction has been associated with protective effects on various diseases, such as cardiovascular disease (McCabe et al., 2002) or wound healing (Detillion et al., 2004). More direct skin-to-skin contact by postnatal stroking stimulation in the rat reduced blood pressure in adulthood (Holst et al., 2002). These protective effects seem to be related to dampened hypothalamic–pituitary–adrenal (HPA) axis and autonomic nervous system (ANS) responses to stress, presumably mediated by central nervous neuroendocrine systems, such as the neuropeptide oxytocin (Carter, 1998; Pedersen and Boccia, 2002).

Although human studies remain relatively limited, initial investigations suggest similar stress-buffering effects of social interactions in humans. Specifically, acute physiological stress reactivity in experimental human studies has also been shown to be responsive to social support (Gerin et al., 1992; Lepore et al., 1993). The presence of a personal friend or spouse has been associated with lower cardiovascular activity (Christenfeld et al., 1997) and blunted activity of the HPA axis (Kirschbaum et al., 1995; Heinrichs et al., 2003). However, similar to the aforementioned epidemiological research, experimental studies too suggest that a greater benefit of verbal social support in couples accrues to men (Kirschbaum et al., 1995). Thus, it is not clear, especially in women, what kind of partner interaction aside from verbal support buffers stress-responsive physiological systems that underlie pathophysiological alterations.

To date, there have been no experimental human studies that directly address the effects of different positive couple interactions on adrenal and autonomic stress reactivity in women. Positive tactile contact is associated with reduced stress-responsive neuroendocrine systems in humans and non-human mammals (Holst et al., 2002; Field et al., 2004; Moyer et al., 2004; Lonstein, 2005). However, there are no studies specifically considering endocrine responses to a laboratory stress test in humans. As a consequence, we hypothesize that standardized physical partner contact (neck and shoulder massage) results in attenuated responses of the HPA axis and the ANS to acute psychosocial stress in women, thereby contributing to a better understanding of the protective mechanisms of positive couple interaction in the prevention of stress-related diseases with major public health significance. We consider that dysregulated stress-related physiological systems might lead to chronic stress and impaired health outcomes (McEwen, 1998). We therefore undertook a randomized controlled trial of the effects of different kinds of couple interaction on cortisol, heart rate, and psychological stress responses.

2. Methods

2.1. Participants

Sixty-seven healthy, heterosexual women, aged 20–37 years, who had been married or cohabiting with a significant other for at least 12 months participated in the study. Exclusion criteria for participation were significant medical or psychiatric illness, substance abuse, medication, smoking, and cortisol levels at baseline more than two standard deviations above the mean of the total group. Eight of the original 75 subjects did not meet the eligibility criteria and were therefore excluded: one woman who had taken hormonal contraceptives, one woman who came alone to the experiment although she was assigned to the physical contact group, one woman who discontinued participation due to language difficulties, and five who exhibited baseline cortisol levels more than two standard deviations above the mean of all women possibly indicative of endocrine

dysfunction or extraordinary stress when anticipating the experiment. All subjects had regular menses and were free of hormonal contraceptives. The experimental sessions were related to the subjects' luteal phase (between day 17 and day 25) of the menstrual cycle. Subjects abstained from exercise, caffeine, and alcohol during the 24 h before the experiment. All sessions commenced between 4.00 p.m. and 7.00 p.m. to control for diurnal changes in cortisol secretion, and lasted for 2 h. Participants were recruited from the Zurich area through posters and newspaper advertisements and were remunerated with 80 Swiss francs per couple for their participation. Subjects were informed about the course and aims of the study and provided written, informed consent prior to participation. The study was approved by the institutional review board of the University of Zurich.

2.2. Procedure

On the basis of random assignment, subjects either received standardized physical contact (i.e., instructed neck and shoulder massage) ($n = 20$), or social support ($n = 22$), or came alone to the experiment without any intervention ($n = 25$). Psychosocial stress was induced by the Trier Social Stress Test (TSST) (Kirschbaum et al., 1993), which primarily consists of a 5-min public speaking task (mock job interview) and a subsequent 5-min mental arithmetic task (serial subtraction) performed out loud in front of an unknown panel of one man and one woman. After being shown the TSST room containing the panel of evaluators and a conspicuous video camera, and after being told about the upcoming task, verbal social support, or physical contact was provided in a small room by the spouse during a 10-min period prior to stress, while subjects of the group without interaction rested quietly alone. After this, all participants were given another 5-min solitary preparation phase for the speaking task, and then participated in the stress test without their spouse present. Numerous studies indicate that the TSST enables a naturalistic exposure to a socio-evaluative stressful situation, with two- to three-fold increases in HPA axis and cardiovascular responses (Kirschbaum et al., 1993; Dickerson and Kemeny, 2004).

2.3. Intervention

Pleasant tactile contacts in animals (Carter, 1998; Holst et al., 2002) and non-sexual, positive physical contacts (e.g., massage and hugging) in humans (Lynch et al., 1977; Grewen et al., 2003; Field et al., 2004; Light et al., 2005) have been shown to be linked to reduced physiological and behavioral stress and anxiety responses. In the physical contact group, subjects received standardized physical contact consisting of a relaxing neck and shoulder massage by their partner. Couples were instructed on how to conduct the massage by an approved physiotherapist of the University Hospital of Zurich 1 week before the experiment in a single 20-min session and were told not to practice the massage more than once until the experiment. In order to avoid habituation effects, this instruction session did not take place in the same building as the stress test and no persons from the subsequent study personnel were present during this session. In the experiment, partners were required to refrain from talking and to exclusively offer the relaxing massage during the 10-min period prior to stress. In the social support group, partners were instructed to provide exclusively verbal support before stress induction. They were told that they would know best what to say to support the subjects' individual coping preferences, as described elsewhere (Kirschbaum et al., 1995; Heinrichs et al., 2003). Subjects of the control group were asked to come alone to the laboratory and were offered no social interaction during the experiment.

To ensure the availability of the partners on the day of the experiment in the two groups with social interaction, all subjects were randomly assigned to one of the three conditions one week earlier. It should be emphasized that no mention was made of the two kinds of instructed social interaction before stress exposure or their possible stress-protective effects, thereby circumventing possible stress-reducing strategies other than the experimentally controlled kinds of interaction (support and massage). Partners in both the physical contact and the social support group left the laboratory immediately after the 10-min interaction period.

2.4. Measures and assays

Numerous studies indicate that salivary free cortisol is considered to be a reliable and valid measure of the biologically active fraction (Vining et al., 1983; Kirschbaum and Hellhammer, 1994). Salivary cortisol levels were collected before (−20 min relative to the TSST) and after intervention (−10 min) using a commercially available sampling device (Salivette; Sarstedt, Rommelsdorf, Germany). Additional samples were collected immediately before (−1 min) and after stress exposure (+1, +10, +25, +40). The Salivette tubes were stored in the laboratory at −20 °C until required for biochemical analysis. Before assaying for free cortisol, samples were thawed and centrifuged at 3000 rpm for 10 min to obtain 0.5–1.0 ml clear saliva with low viscosity. The free cortisol concentration in saliva was analyzed using a commercially available chemiluminescence immunoassay (CLIA; IBL-Hamburg, Germany). Inter- and intraassay coefficients of variation were 8.4% and 4.6%, respectively. No subject was excluded from the analyses due to missing cortisol measures.

The hormone oxytocin has been shown to decrease basal cortisol levels following systemic administration in humans (Legros et al., 1984, 1988), and positive physical contact (i.e., massage) has been shown to slightly stimulate plasma levels of oxytocin in women (Turner et al., 1999). Furthermore, brain oxytocin has behavioral and physiological stress-attenuating effects (Neumann et al., 2000a) and promotes social behavior, including pair bonding, maternal behavior, sexual behavior, and social attachment in animals (Carter, 1998; Uvnas-Moberg, 1998a; Insel and Young, 2001; Pedersen and Boccia, 2003; Young and Wang, 2004). Although plasma concentrations of oxytocin do not seem to reflect the central nervous availability of the neuropeptide (Landgraf and Neumann, 2004), we controlled for

possible attenuating effects of plasma oxytocin levels on cortisol stress responses (Legros et al., 1984, 1988). Catheters were inserted into a forearm vein 45 min prior to the baseline sample and were kept patent by means of normal saline infusion. Blood samples were collected before (−20 min relative to the TSST) and after the intervention phase (−10 min) and immediately after cessation of stress (+1 min) for determining oxytocin. Blood samples were collected on ice in EDTA-coated tubes, centrifuged at 4 °C at 5000 rpm for 5 min, and stored at −80 °C until assay. Oxytocin concentrations were analyzed in extracted plasma samples by a highly sensitive and selective RIA with a cross-sensitivity with related neuropeptides of 0.7%, described elsewhere (Landgraf et al., 1995). Catheter insertion and subsequent blood collection failed in three subjects due to inaccessibility of the veins. In three additional subjects, blood samples were hemolytic and could not be analyzed, resulting in valid oxytocin samples in 61 subjects (no interaction: $n = 22$, social support: $n = 22$, physical contact: $n = 17$).

Heart rate, as an indicator for autonomic stress responsiveness, was measured using a portable heart rate monitoring device (Polar S810, Polar Electro Oy, Kempele, Finland), with aggregated beat-to-beat analyses in 1-min intervals (beats/min) from −5 to +5 min relative to the stressor (20 units). Heart rate measures of 19 subjects were incomplete due to technical problems and had to be excluded from analyses, resulting in 48 complete heart rate files available for analysis (no interaction: $n = 15$, social support: $n = 18$, physical contact: $n = 15$).

Subjects completed questionnaires designed to measure demographic items, relationship satisfaction, personality characteristics, and psychopathological symptoms. State anxiety was repeatedly assessed before and after stress exposure. The stressfulness of the test was determined using visual analog scales (VAS) that are especially suited for the assessment of acute stress. The validated German versions of the following questionnaires were included: the State-Trait Anxiety Inventory (STAI) (Laux et al., 1981), the Self-Rating Depression Scale (SDS) (Zung, 1965), the Interpersonal Support Evaluation List (ISEL) (Laireiter, 1996), the Marriage Diagnostic Questionnaire (FPD) (Hahlweg, 1996), and the Trier Inventory for the Assessment of Chronic Stress (TICS-2) (Schulz et al., 2004). All of these questionnaires have been broadly used and have shown high internal consistency and validity.

2.5. Data analysis

Cortisol, oxytocin, and heart rate data were analyzed using two-way analyses of variance (ANOVA) with repeated measurement (group [three groups] by time [repeated factor: 7 for cortisol, 3 for oxytocin, and 20 for heart rate]). Saliva cortisol measures were log-transformed applying the general formula: $\ln x = \ln(x+1)$. We verified repeated-measures results using Greenhouse–Geisser corrections where appropriate (heterogeneity of error covariances in the Mauchly test of sphericity), reflected by the degrees of freedom with decimal values. Homogeneity of variance was assessed using the Levene test. The areas under the individual response curves with respect to increase (AUC_I) of cortisol and heart rate were calculated with the trapezoid formula, which allows a sensitive measure of physiological changes over time (Pruessner et al., 2003). Significant differences of post hoc comparisons among groups were calculated with the Tukey-HSD test. All analyses were two-tailed, with the level of significance set at $p < .05$.

3. Results

3.1. Description of the study groups

There were no statistical differences among the three groups in terms of age, body mass index, duration of relationship, or relationship satisfaction. Subjects in the three comparison groups did not differ with respect to trait anxiety, depressive symptoms, perceived availability of general social support, and chronic stress, with all psychopathological symptoms being in the normal range of the general population (Table 1). The massage instructions given 1 week before the experiment did not influence any physiological or psychological outcome variables, as indicated by identical baseline cortisol (two baseline measures before stress), heart rate (five baseline measures before stress), and anxiety levels before stress among groups.

3.2. Endocrine responses to stress

3.2.1. Cortisol

Results obtained by two-way ANOVA with repeated measures indicated that the stress protocol induced significant increases in log-transformed salivary free cortisol levels

Table 1 Description of the study groups.

Characteristic	No interaction ($n = 25$)	Social support ($n = 22$)	Physical contact ($n = 20$)	ANOVA p
Age (years)	26.8 (4.7)	26.6 (4.2)	25.7 (3.7)	.64
Body mass index (kg/m^2)	22.1 (4.5)	21.4 (2.7)	20.7 (2.0)	.40
Duration of relationship (years)	3.8 (2.4)	3.6 (2.8)	4.6 (3.0)	.36
Relationship satisfaction (FPD)	4.4 (.65)	4.4 (.90)	4.0 (1.0)	.25
Trait anxiety (STAI)	37.7 (9.8)	37.1 (7.0)	40.1 (10.5)	.56
Depression (SDS)	42.2 (9.4)	40.8 (6.9)	44.2 (7.8)	.39
Social support (ISEL)	74.4 (19.8)	75.3 (15.0)	81.7 (18.9)	.39
Chronic stress (TICS)	7.9 (3.1)	8.4 (2.4)	8.9 (2.3)	.47

Data are expressed as mean (SD).

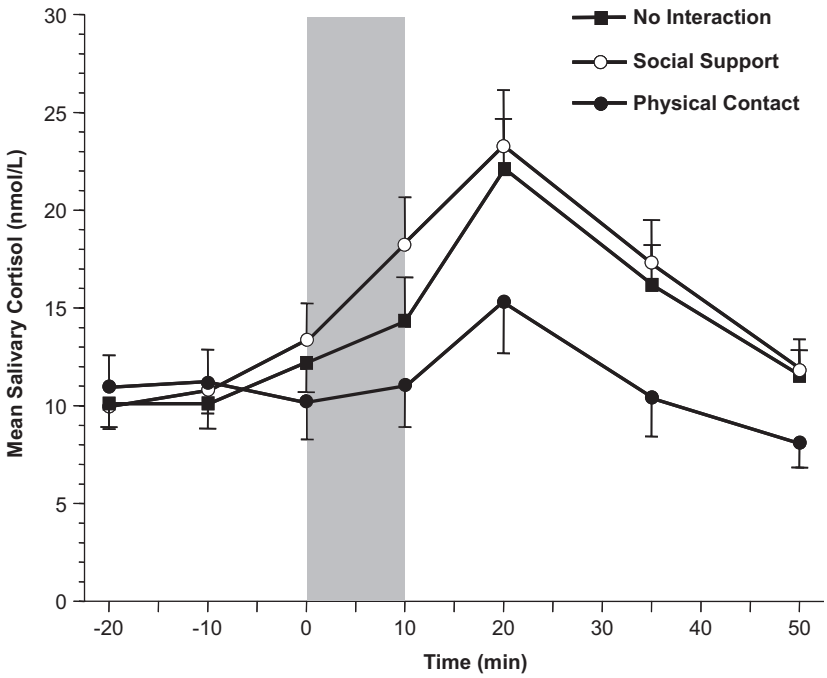

Figure 1 Mean salivary cortisol concentrations before, during (shaded area), and after a standardized psychosocial stressor (Trier Social Stress Test) in women with no social interaction, women with verbal social support by the partner, and women with physical partner contact (neck and shoulder massage) during a 10-min period prior to stress. Error bars are standard errors of the mean (SEM). To convert cortisol from nmol/l to mg/dl, divide by 27.59.

(main effect of time: $F[2.16,138.0] = 20.90$, $p < .001$) in the total group of women (Fig. 1). No significant differences in basal cortisol levels were observed among the three groups before intervention ($F[2,64] = 0.42$, $p = .66$). There was a significant group by time interaction effect ($F[4.31,138.0] = 2.64$, $p < .05$), with the lowest cortisol responses to stress in the physical contact group. In addition, there was a significant main effect of group on the total amount of cortisol increase (AUC_I) ($F[2,64] = 3.29$, $p < .05$), indicating the lowest increase of cortisol concentration in the physical contact group. No main effect of group was observed on repeated-measures cortisol levels ($F[2,64] = 1.21$, $p = .30$). The mean absolute increase in salivary cortisol in response to stress was 11.98 nmol/l in subjects with no interaction, 13.29 nmol/l in subjects of the social support group, and 4.33 nmol/l in subjects with positive physical contact. Post hoc analyses (Tukey-HSD test) revealed significant differences in the AUC_I of log-transformed cortisol levels between the physical contact and no interaction groups (mean difference = 2.99, $p = .05$; 95% confidence interval = −6.0 to 0.004).

3.2.2. Oxytocin

No significant changes in oxytocin plasma levels were observed throughout the experiment (main effect of time: $F[2.0,58.0] = 0.37$, $p = .55$; main effect of group: $F[2,58] = 0.75$, $p = .48$; group by time interaction: $F[2.0,58.0] = 0.98$, $p = .38$).

3.3. Heart rate responses to stress

A two-way ANOVA with repeated measures revealed the expected significant heart rate response to stress (main effect of time: $F[5.01,225.60] = 57.79$, $p < .001$) across all groups (Fig. 2). No significant differences in heart rate levels were observed among groups before stress ($F[2,45] = 0.13$, $p = .88$). There was no significant main effect of group ($F[2,45] = 1.95$, $p = .15$) and no significant group by time interaction on repeated heart rate measures ($F[10.03,225.60] = 0.79$, $p = .64$). However, a significant main effect of group for the total amount of heart rate increase (AUC_I) was obtained ($F[2,45] = 4.46$, $p < .05$), with the lowest increase of heart rate in the physical contact group. The mean absolute increase in heart rate in response to stress (mean heart rates before stress compared to mean heart rates during stress) was 30.63 beats/min in subjects with no interaction, 26.70 beats/min in subjects in the social support group, and 18.82 beats/min in subjects with positive physical contact. Post hoc analyses (Tukey-HSD test) revealed significant differences in the AUC_I between the physical contact and control groups (mean difference = 193.48, $p < .05$; 95% confidence interval = −358.05 to −28.92), and a trend toward differences between the physical contact and social support groups (mean difference = 146.09, $p = .07$; 95% confidence interval = −303.65 to 11.47).

3.4. Psychological responses to stress

3.4.1. Anxiety

State anxiety (STAI) significantly decreased from pre to post stress in the total group (main effect of time: $F[1.0,63.0] = 6.53$, $p < .05$). This effect was not influenced by group assignment (group by time interaction:

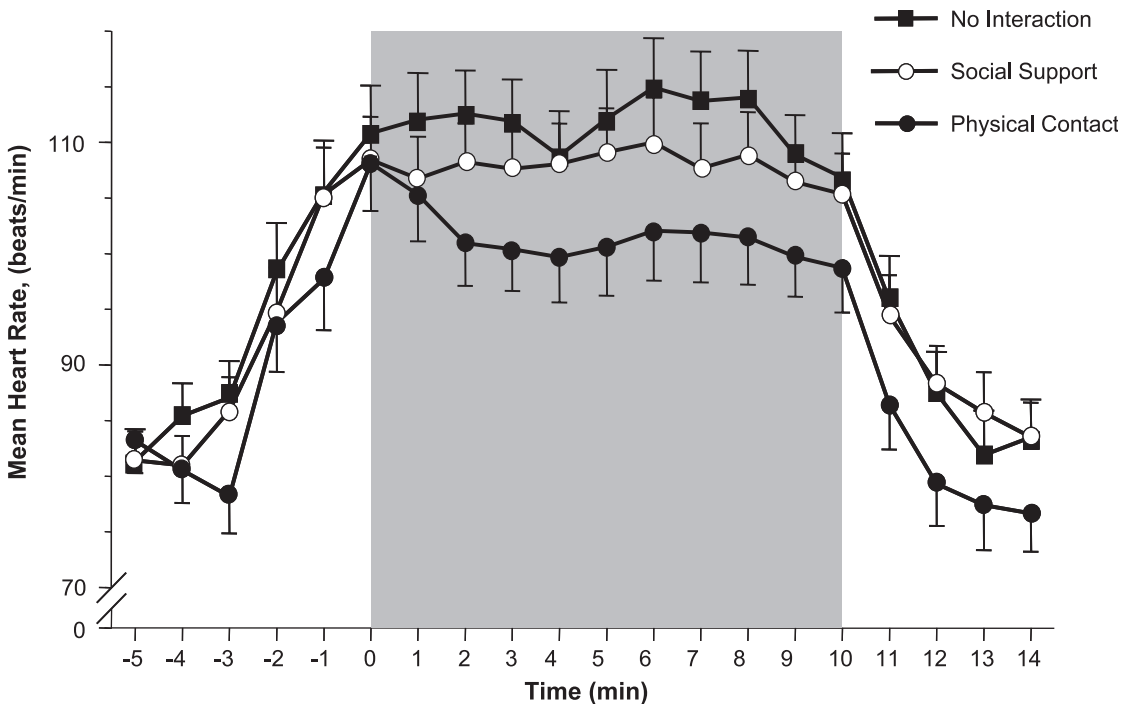

Figure 2 Mean heart rates before, during (shaded area), and after the Trier Social Stress Test in women with no social interaction, women with verbal social support by the partner, and women with physical partner contact (neck and shoulder massage) during a 10-min period prior to stress. Error bars are SEM.

$F[2.0,63.0] = 0.69$, $p = .51$) and there was no main effect of group on state anxiety ($F[2,63] = 1.20$, $p = .31$).

3.4.2. Stress evaluation

No significant differences in perceived stressfulness (VAS) in response to stress were observed among groups ($F[2,67] = 0.77$, $p = .47$). There were no significant correlations between psychological stress responses and physiological stress responses (all $r < .19$). The quality of the couple relationship (FPD) did not affect physiological stress responses (ANCOVAs with relationship quality as covariate by group by time with cortisol, oxytocin, and heart rate measures, respectively: relationship quality × time interactions: all $F < 1.05$). Neither did any of the control variables (depressive symptoms, general anxiety, chronic stress, and generally available social support) have a significant main effect or interaction effect with the group factor on heart rate or cortisol responses in our sample.

4. Discussion

In this randomized controlled study investigating stress-protective effects of specific kinds of couple interaction, we found that positive physical contact provided by the partner before stress significantly reduced subsequent salivary free cortisol responses to psychosocial stress in women. In addition, physical contact from the partner resulted in significantly reduced heart rate increase in response to the standardized laboratory stressor, whereas verbal social support alone was not associated with reduced stress responsiveness. Notably, these effects occurred despite the fact that the partner had already left the laboratory prior to the stressor, thereby circumventing a possible distraction from the stressor by the presence of the partner. These findings in women raise the possibility that specific kinds of couple interaction might protect against exaggerated physiological stress responses more effectively than others. Thus, physical touch as a couple-specific behavior might prevent higher cumulative overall health risk (e.g., cardiovascular disease) caused by daily stress over time (McEwen, 1998; Kiecolt-Glaser and Newton, 2001; Robles and Kiecolt-Glaser, 2003). Our results are also remarkably consistent with protective effects of physical contact reported in laboratory animal studies (Carter, 1998; Lonstein, 2005).

Findings from epidemiological studies provide evidence that social support exerts powerful beneficial effects on health outcomes and longevity (Broadhead et al., 1983; House et al., 1988; Uchino et al., 1996; Seeman, 2000; Cohen, 2004). More specifically, in numerous studies, being married or cohabiting with a significant other has been associated with lower rates of morbidity and mortality compared with nonmarried individuals (Case et al., 1992; Williams et al., 1992; Johnson et al., 2000; Kiecolt-Glaser and Newton, 2001). Existing evidence suggests that these associations cannot be accounted for on the basis of established risk factors or health behaviors alone (Burman and Margolin, 1992; Kamarck et al., 1995). Studies suggest that there are gender differences in terms of how and what type of support benefits women and men (Cutrona, 1996; Schmaling and Goldman Sher, 2000; Taylor et al., 2000; Bodenmann and Shantinath, 2004; Revenson et al., 2005). For example, men are more than twice as likely as women to name their spouse as their primary provider of social support (Karasek et al., 1981). Another gender-specific finding is

that marital stress predicts higher mortality risks in women with coronary heart disease, while work stress does not (Orth-Gomer et al., 2000). It is important to note that these gender-specific epidemiological findings have been confirmed by endocrine and subjective responses to acute psychosocial laboratory stress in humans (Kirschbaum et al., 1995; Glynn et al., 1999). Whereas men showed significant attenuation of cortisol responses to stress when supported by an opposite-sex stranger or by their spouse, women showed no response decrement under these social support conditions. Moreover, women showed a tendency toward increased cortisol responses when supported by their spouse (Kirschbaum et al., 1995). In another study on gender, social support, and physiological stress responses, social support by a woman was shown to be more effective in reducing blood pressure responses to stress in both men and women than support by a man (Glynn et al., 1999). It should be emphasized that both of these studies specifically investigated the effects of verbal social support. Thus, it remains unclear from previous research how couple relationships might improve health in women. Our present data replicate and extend the gender-specific effects of couple support on stress responsiveness in women. Although women did not seem to benefit from their partners' verbal support, positive physical contact before stress exposure reduced endocrine and autonomic stress responses.

What are the putative mediators between physical contact and stress response? In non-human mammals, the stress-buffering effect of proximity and affiliation has been shown to be mediated by the activation of specific central nervous neuroendocrine systems. For instance, the activity of endogenous opioid neurons originating in the arcuate nucleus of the hypothalamus was shown to reduce stress and anxiety behavior and to signal rewarding aspects of social interaction in rodents (Kuhn and Schanberg, 1998). It has been suggested that physical contact between mother and infant also activates the opiate systems in humans (Kalin et al., 1995). In other studies, touch has been linked to increased levels of serotonin (Field et al., 1996), which were shown to reduce psychosocial stress reactivity in animals and in humans (Hanley and Van de Kar, 2003). In particular, the neuropeptide oxytocin has been shown to play a central role in the social modulation of stress responses in various regions of the limbic system (Carter, 1998; Uvnas-Moberg, 1998b; Landgraf and Neumann, 2004). Oxytocin attenuates behavioral, endocrine, and autonomic responses to stress following both endogenous stimulation by lactation, touch, and physical proximity (Carter and Altemus, 1997; Uvnas-Moberg, 1997; Carter, 1998; Neumann et al., 2000a; Holst et al., 2002; Lund et al., 2002), and exogenous stimulation by intracerebral (Petersson et al., 1996; Windle et al., 1997, 2004) or intranasal (Parker et al., 2005) administration in animals. In accordance with the animal literature, recent studies in humans suggest that oxytocin plays a role in the reduction of physiological responses to stress after endogenous stimulation by breastfeeding (Altemus et al., 1995; Heinrichs et al., 2001, 2002). However, in contrast to animal research, oxytocin cannot be directly measured in the human brain. Furthermore, in animal studies, virtually no correlation has been shown between plasma oxytocin and oxytocin in the brain (Landgraf and Neumann, 2004). In humans, studies on behavior and peripheral oxytocin have shown equivocal findings. Whereas some recent studies reported a relation between plasma oxytocin and psychological variables (Fries et al., 2005; Grewen et al., 2005), others did not find changes in plasma oxytocin following stress or positive interaction in the laboratory (Altemus et al., 2001; Taylor et al., 2006). In the current study, we found no changes in oxytocin plasma levels in the three comparison groups, indicating that the reduced salivary cortisol levels in women who received massage before stress might not be explained by inhibitory effects of circulating oxytocin at the adrenal level. Rather, this might lead to the hypothesis that close physical contact is linked to the stimulation of intracerebral oxytocin and to inhibitory actions of oxytocin at higher brain levels, as shown in animal studies (Neumann et al., 1993, 2000b; Windle et al., 2004). Our recent demonstration of the anxiolytic effects from intranasally administered oxytocin implies that the buffering effects of social support may take place in the central nervous system. This latter study showed that intranasally administered oxytocin increased the buffering effect of social support on adrenal and subjective stress responses in men (Heinrichs et al., 2003). In accordance with its effects on prosocial approach behavior in animals, we recently showed that intranasal oxytocin increased trust in humans (Kosfeld et al., 2005).

In contrast to the physiological findings, the three study groups did not differ in their psychological stress responses. This dissociation between behavioral and physiological stress response concurs with earlier studies on stress-reducing effects of lactation in animals and humans in which lactation significantly reduced HPA axis responses to stress with normal behavioral stress reactivity (Walker et al., 1995; Heinrichs et al., 2002). While possible protective effects of social support have been explained by a less threatening and more controllable perception of a stressor, with the supporting person presumably acting as a "safety signal" (Kirschbaum et al., 1995; Heinrichs et al., 2003), positive physical contact seems to reduce physiological stress responses by activating neuroendocrine systems that are associated with the control of the HPA axis and the SAM system beyond subjective awareness.

Our data do not answer the question of whether increasing supportive touch in troubled marriages may improve the relationship and ultimately the health benefits of the relationship. The quality of the relationship appears to play an essential role in health outcomes, with low marital satisfaction linked to higher health risk (Orth-Gomer et al., 2000; Coyne et al., 2001; Matthews and Gump, 2002). In our study, the quality of the relationship did not influence the effect of touch versus verbal social support on physiological stress levels; nor did any other control variable, like depression rating. The findings on relationship quality are in accordance with data reported by Gump et al. (2001). In their study, the blood pressure reducing effect of interactions with the intimate partner compared to interactions with others and no interactions was not moderated by relationship quality. Since our study examined healthy women with high couple satisfaction, it might not be possible yet to generalize our findings to those in troubled marriages. Accordingly, our results may not speak for women suffering from psychiatric or physical disorders or intimate partner violence, all factors that were shown to influence psychophysiological stress

responses (Pico-Alfonso et al., 2004). It could be argued that happy couples touch each other more often than unhappy couples, and that this mediates the long-term health-promoting effects of happy relationships via the biological pathways mentioned above. Future studies should include subgroups of couples with different levels of relationship quality in order to discern the interaction of relationship satisfaction and physical contact in coping with stress.

In summary, although the reported results need to be replicated to allow firm conclusions to be drawn, we propose that touch and possibly physical proximity specifically explain one aspect of the health-promoting effects of close relationships. Whereas men receive better health outcomes from being and staying married and, in contrast to women, show immediate benefits from verbal social support by their partner, our findings in women suggest that not social support, but rather affectionate physical partner interaction markedly contributes to lower neuroendocrine and cardiovascular reactivity to stressful life events. These protective effects might presumably be mediated by central nervous neuroendocrine systems (e.g., oxytocin and opioids), which in turn attenuate HPA axis and ANS responses to stress (Carter, 1998; Heinrichs et al., 2002, 2003). Further studies should explore a possible interaction of combined physical contact and social support before stress. Furthermore, it would be informative to directly compare our findings in both men and women in order to examine potential gender-specific kinds of protective interaction in couples (Cutrona, 1996). Interestingly, Grewen et al. (2003) previously found that a 10-min period of hand holding and hugging attenuated cardiovascular activity in both genders, suggesting that men, besides the effects of verbal social support, may also benefit from physical contact. Finally, research on marital counseling and therapy should focus not only on risk factors such as hostility and conflict during couple interaction, but also carefully consider touch and various forms of support as potential mediators of the known health advantages attributable to close relationships.

Role of the funding source

This research was funded by Swiss National Science Foundation (SNSF) grants 105313-109408 and PP001-114788 (to M.H.), a Scholarship of the German Academic Exchange Service (DAAD) (to B.D.), and Swiss National Science Foundation Postdoctoral Research Stipend PBZH1-108392 (to B.D.). This paper is part of the Research Priority Program ''Foundations of Human Social Behavior'' at the University of Zurich. The SNSF, DAAD, and the Research Priority Program had no further role in the study design, data collection, analysis, and interpretation of data, writing of the report, or decision to submit the paper for publication.

Conflict of interest

Beate Ditzen: NONE
Inga D. Neumann: NONE
Guy Bodenmann: NONE
Bernadette von Dawans: NONE
Rebecca A. Turner: NONE
Ulrike Ehlert: NONE
Markus Heinrichs: NONE

Acknowledgments

This research was funded by Swiss National Science Foundation (SNSF) Grants 105313-109408 and PP001-114788 (to M.H.), a Scholarship of the German Academic Exchange Service (DAAD) (to B.D.), and Swiss National Science Foundation Postdoctoral Research Stipend PBZH1-108392 (to B.D.). This paper is part of the Research Priority Program ''Foundations of Human Social Behavior'' at the University of Zurich. Massage oil was supplied by Weleda (Arlesheim, Switzerland). We would also like to thank Juliane Emmerich, M.Sc., Martina Hofmanner, M.Sc., Philip Lutholf, M.Sc., Urs Nater, Ph.D., and Annina Pult, M.Sc., for their skilled assistance in the performance of this study. We thank Jens B. Asendorpf, Ph.D., for consultation on relationship and personality assessment and Sarah Mannion, M.Sc., for editing assistance.

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