RUNNING HEAD: Social Support Buffers HPA Axis

The Buffering Effect of Social Support on Hypothalamic-Pituitary-Adrenal Axis Function During Pregnancy

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Abstract

Objective: Recent studies suggest that effective social support during pregnancy may buffer adverse effects of maternal psychological distress on fetal development. The mechanisms whereby social support confers this protective advantage, however, remain to be clarified. The aim of this study was to assess whether individual differences in social support alter the co-variation of psychological distress and cortisol during pregnancy.

Methods: Eighty two pregnant women's psychological distress and cortisol were prospectively assessed in all three trimesters using an ecological momentary assessment strategy. Appraisal of partner social support was assessed in each trimester via the Social Support Effectiveness questionnaire.

Results: In multilevel analysis, ambulatory assessments of psychological distress during pregnancy were associated with elevated cortisol levels, unstandardized $\beta = .023$, $p < .001$. Consistent with the stress buffering hypothesis, social support moderated the association between psychological distress and cortisol, unstandardized $\beta = -.001$, $p = .039$, such that the co-variation of psychological distress and cortisol increased with decreases in effective social support. The effect of social support for women with the most effective social support was a 50.4% reduction in the mean effect of distress on cortisol and a 2.3 fold increase in this effect for women with the least effective social support scores.

Conclusions: Pregnant women receiving inadequate social support secrete higher levels of cortisol in response to psychological distress as compared to women receiving effective social support. Social support during pregnancy may be beneficial because it decreases biological sensitivity to psychological distress, potentially shielding the fetus from the harmful effects of stress-related increases in cortisol.

Keywords: Social Support, Psychological Distress, Salivary Cortisol, Pregnancy, HPA Axis, Biobehavioral Coherence.

GA= gestational age; SSE= social support effectiveness questionnaire; POMS= profile of mood states; PDA= personal digital assistant.

Introduction

Perceived access to effective social support is a major determinant of physical (1-3) and psychological well-being (4-6) across the lifespan. Social support may be especially important during times of stress or major life transition, such as pregnancy (7, 8). Pregnant women who are in supportive relationships engage in healthier behaviors during pregnancy (9), report lower levels of psychological distress (8), and give birth to healthier infants (10) compared to women with inadequate support. These findings are consistent with the suggestion that social support may buffer the effects of psychological distress during pregnancy (8) on adverse obstetric, birth, and developmental outcomes (11-15).

The effects of psychological distress during pregnancy on fetal development are presumed to be mediated by the maternal stress response systems, which are activated by perceptions of stress. Cortisol, the end product of the Hypothalamic Pituitary Adrenal (HPA) axis, has been extensively investigated as a plausible biological mechanism responsible for embedding maternal experience within fetal development. Maternal cortisol may reach the fetus directly, passing across the placenta despite (partial) conversion of cortisol to its inert form by 11 beta-hydroxysteriod type 2 (16, 17). Active cortisol can then easily pass through the blood-brain barrier of the fetus, influencing development of the fetal nervous system (18, 19). Because fetal cortisol concentrations are so much lower than maternal concentrations, even slight variations in maternal cortisol can significantly affect fetal glucocorticoid exposure (16). Maternal cortisol may also affect the fetus indirectly, via its influence on placental production of corticotrophin-releasing hormone (CRH) (20). Although cortisol is required for the maturation of fetal organs (21) and neural generation (22) prior to parturition, excessive or prolonged secretion of cortisol during pregnancy is associated with impaired fetal development (23-25).

During pregnancy, the maternal HPA axis undergoes dramatic changes in function (26). For instance, cortisol levels increase two- to four-fold due in part to the stimulatory effect of placental corticotrophin- releasing hormone on the maternal pituitary (27). Despite these changes, the normal diurnal pattern of cortisol (i.e., high upon awakening followed by decreases over the course of the day) is preserved (28), as is responsiveness to psychological distress (29). Contrary to common belief, the co-variation between cortisol and psychological distress does not appear to attenuate with advancing gestation (30). The effects of social support on HPA axis function during pregnancy have not been reported.

As originally conceptualized by Cohen (31, 32), the buffering hypothesis predicts that the magnitude of a stress response in individuals with relatively low levels of effective social support will be commensurate with the potency of the perceived threat, danger, or challenge, whereas stress responses should be similarly small across all levels of stressors among individuals with relatively high levels of effective social support. The buffering hypothesis has been supported by studies showing that the biological and/or psychological relevance of a stressor are reduced when support is accessible (33-36). Although a large body of literature examines the role of social support as a buffer to the detrimental effects of psychological distress, the mechanisms through which it promotes maternal and fetal health during pregnancy remain to be clarified.

Building on existing theories about emotional and social support, the current study was designed to determine whether social support during pregnancy may alter *biobehavioral coherence* – the extent to which psychological and biological changes co-vary within an individual over time. Emotionally arousing experiences are expected to activate behavioural and physiological systems (37), and a central postulate of emotion theory has been the notion that emotional responses are coordinated across both behavioural and physiological systems (38).

Based on our application of the buffering hypothesis, we reasoned that effective social support has the potential to reduce maternal neuroendocrine responses to negative emotional experience – that is, to reduce the biobehavioral coherence between psychological and physiological systems. Specifically, we hypothesized that changes in cortisol would be more closely associated with concurrent changes in psychological distress among pregnant women who reported receiving relatively low levels of effective social support as compared to women who reported receiving relatively high levels of effective social support.

Method

Participants

Eighty-five pregnant women who were enrolled in an ongoing longitudinal study of nutrition during pregnancy (see www.apronstudy.ca for further details) participated. Women were excluded if they were >14 weeks gestation or if they reported any of the following: a) taking a steroid medication, b) smoking, c) consuming alcohol or 'street' drugs, d) recent dental work or tendency for oral bleeding (potentially leading to falsely elevated cortisol values (39)), e) known fetal or pregnancy complications (e.g., preeclampsia, fetal genetic anomalies, gestational diabetes), or f) illness during data collection (e.g., fever). Prior to data collection, participants provided informed consent. The study procedures were approved by the University of Calgary Conjoint Health Research Ethics Board. Data were collected between July 2010 and June 2011.

At enrollment, participants had a mean age of 31.7 years (SD = 3.8), were married or living common law (98.8%), had an average of 2.1 previous pregnancies (SD = 1.1), 34.9% were nulliparous, 70.6% had a university degree and 9.4% had a high school diploma or less, 62.4% had household income above $100,000 (Canadian dollars) and 5.9% had income less than

$40,000 per year, 61.5% were working full time and 21.8% were working part time, and 91.7% were White.

Procedures

Participants completed the sampling procedures three times during pregnancy: prior to 14 weeks gestational age (GA) (M = 12.9, SD = 2.7), at ~ 20 weeks GA (M=19.3, SD = 1.2), and at ~ 32 weeks GA (M = 32.4, SD = 0.9). On each assessment occasion, women self-collected saliva at home over 2 consecutive days (excluding weekends in order to rule out potential weekend-weekday differences in stress and diurnal cortisol (40)) for a total of 6 days over the course of the study. Samples were obtained on the following schedule: upon waking (allowing for individualized wake times), 30 minutes after waking, and semi-randomly after the anchor times of 1100h, 1530h, and 2000h. Following procedures described by Smyth and colleagues (41), semi-random signals occurred on a personal digital assistant (PDA) once within 15 minutes following the anchor times to minimize changes in mood associated with anticipation of the signal. To facilitate adherence to the study protocol, the PDA was programmed to allow a 20 minute response window following the signal, after which data were considered missing.

Each time the PDA rang, it first provided a unique code corresponding to a pre-labeled saliva tube and instructed the participant to place the saliva roll under her tongue. Participants then completed the PDA-administered psychological distress questionnaire during saliva collection. Time of each assessment was recorded by the PDA, permitting precise modeling of diurnal patterns.

Measures

Social Support Effectiveness. Women's perception of social support received from their romantic partner was assessed via the Social Support Effectiveness questionnaire (SSE), a 35-

item measure of emotional, informational, task, and negative support received over the previous 3 months. Within each domain, women were asked to rate (a) how well the quantity of support received from her partner matched the amount she wanted (0 = *it was far too little or too much help* to 4 = *it was exactly the right amount of help*); (b) whether she wished the support had differed somehow (e.g., "to what extent did you wish your partner had offered a different *type* of help, or offered it in a different *way* or at a different *time*?" 0 = *extremely* to 4 = *not at all);* (c) how skillful her partner was at providing support (0 = *not at all* to 4 = *extremely*); (d) how often it was difficult to solicit support (0 = *always* to 4 = *never*); and (e) if her partner offered support without being asked (0 = *never* to 4 = *always*). Ten items assess negative support, or the extent to which a respondent perceived her partner's support as negatively infringing on her own efficacy/self-esteem (e.g., "when you received help or support from this person, did it make you feel incompetent?" 0 = *yes* or 2= *no).* Total scores of the scale can range from 0 to 80, with higher scores indicating more effective support. Internal consistency of the SSE is strong (Cronbach's α = .87) and it has previously been used to distinguish levels of social support in samples of pregnant women (8, 42). The SSE can be used to assess support received from a romantic or non-romantic partner. All women in this study reported being in a romantic relationship and they were therefore asked to complete the questionnaire with regard to their romantic partner.

Cortisol. Participants were asked to refrain from consuming food, caffeine, citric drinks and dairy, to avoid vigorous exercise or brushing teeth in the 30 minutes prior to the sample collection anchor times of 30 minutes post waking, 1100h, 1530h, and 2000h, and to report adherence to these guidelines. Whole saliva was obtained from under the tongue. Saliva samples were stored at -20 C until they were shipped frozen to Salimetrics, State College, PA. All

samples were assayed for salivary cortisol using a highly sensitive enzyme immunoassay. The test has a lower limit of sensitivity of 0.003 µg/dl, standard curve range from 0.012 to 3.0 µg/dl, and average intra-and inter-assay coefficients of variation 3.5% and 5.1% respectively. Method accuracy, determined by spike and recovery, and linearity, determined by serial dilution are 100.8% and 91.7%. A random 10% of samples were assayed in duplicate to confirm reliability; the intra-assay coefficient of variation was 4.16% and the correlation coefficient between the duplicate tests was $r = .99$, $p < .001$. The mean value from duplicate samples was used for data analysis.

Psychological Distress. Psychological distress at each sampling moment was measured using items from the Profile of Mood States (POMS) (43), a multidimensional measure of mood with strong psychometric properties (e.g., coefficient alpha values range .79 - .93) (44). Following procedures described by Cranford and colleagues (45), we selected 19 items from the anger, anxiety, depression, fatigue, and vigor scales with the highest factor loadings from a factor analysis conducted by McNair and colleagues (43). Our measure was the same as the one used by Cranford et al., except that our version of the momentary POMS included 2 additional items for the depression and anxiety scales. Participants rated each item on a 5-point Likert scale from *not at all* to *extremely*, based on their feelings during the previous 30 minutes. The 30 minute window was chosen to account for the delay in HPA axis response to psychological experience (46). As per standard scoring procedures for the POMS, a total mood disturbance score – referred to here as psychological distress - was derived for each sampling moment by subtracting the vigor subscale from the sum of the remaining subscales. In two separate ambulatory studies, Cranford and colleagues (45) demonstrated that a short version of the POMS administered via

PDA had appropriate reliability to detect within-person changes in mood; validity was supported by demonstrating sensitivity to mood changes in participants experiencing a major life stressor.

Statistical Procedures

Multilevel equations were specified at three levels to account for the nested data structure (measurement moments nested within trimester and trimester nested within persons). At level-1 (moment-level), the between-moment variability in the log of cortisol for each individual was modeled as a function of time and psychological distress. In order to isolate within-person covariation between psychological distress and cortisol, psychological distress was person-centered (47). The primary goal was to determine whether social support alters the within-person association between psychological distress and cortisol. Accordingly, the focus of the analysis was on the level-3 submodel for the slope of psychological distress, with social support included as a potential moderator. The following model served as the basis for these analyses:

Level 1: $\text{logCortisol}_{ijk} = \pi_{0ijk} + \pi_1\text{CAR}_{ikj} + \pi_2\text{Time Since Waking}_{ijk} + \pi_3\text{Time Since Waking}_{ikj}^2 + \pi_4\text{Psychological Distress}_{ijk} + \sigma_{ijk}$

Level 2: π_{0jk} through $\pi_{4jk} = \beta_{00k} + \beta_{01k}\text{Gestational Age}_{jk} + \varepsilon_{0jk}$

Level 3: $\beta_{40k} = \gamma_{000} + \gamma_{001}\text{Social Support}_k + u_{00k}$

where logCortisol_{ijk} is the natural log of salivary cortisol for moment i, trimester j, and person k. CAR represents a dummy variable (1 = sample taken 30 minutes after waking) included to model the initial increase in cortisol after waking. Time was parameterized as both time since waking (in hours), as well as time since waking squared to better model the curvilinear shape of the diurnal cortisol curve over the course of the day. Momentary psychological distress refers to POMS total mood disturbance. Social support refers to the individual mean SSE score across all

three assessments – it was grand mean centered. All variables (with the exception of CAR) were modeled as continuous.

Data were analyzed with HLM 7.0 software (48). Missing data were estimated using full information maximum likelihood, which makes full use of all data that is present, even for persons with missing data. All HLM results reported here represent the final estimation of fixed effects with robust standard errors.

Results

Missing Data and Adherence

Of the 85 participants with complete data in the 1st trimester, three were excluded because they miscarried after the first assessment. Of the remaining 82 participants, 78 had data in the 2nd trimester and 76 had data in the 3rd trimester. Participants who did not provide data in the 3rd trimester did not differ from participants with complete data on any of the demographic or study variables. Out of a total possible 2460 saliva samples, 1956 valid saliva samples were available for analysis. Approximately half of the missing samples were due to participant attrition; the other half were missing because of insufficient quantity of saliva to conduct the assay (n = 21), PDA failure (n = 14), participant was busy (n = 116), experimenter error (n = 22), illness (n = 5), and other reasons not specified (n = 86).

Overall adherence to the protocol was very good. The mean and median delay between waking and collection of the 30 minute post waking sample were 34.4 (SD = 6.7) and 33 minutes respectively. The occurrence of brushing teeth and exercising prior to sample collection was rare (2.0% and 0.4%, respectively), whereas consuming food within 30 minutes of sample collection was more common, 11.7%. Preliminary analysis revealed that results were identical with or without inclusion of these covariates and they were therefore excluded from further analysis.

Descriptive Statistics

Total SSE scores increased slightly over the course of pregnancy (M = 59.2, 60.7, and 61.1 respectively for 1st, 2nd, and 3rd trimesters) but this increase was not statistically significant, $F(2, 214) = .52$, $p = .52$. Total SSE scores ranged between 17 and 80, suggesting good variability of support within the sample. Within persons, social support was highly stable over the course of pregnancy; the intraclass correlation for single measures = .80 and for average measures = .92 using an absolute agreement definition. Descriptive statistics for study variables are presented in Table 1 with women grouped into quartiles using 1st trimester SSE total scores.

As indicated in Table 1a, the diurnal pattern of cortisol was preserved across all levels of social support (Tables 1b and 1c reflecting 2nd and 3rd trimester values are available online). Mean scores for cortisol did not differ across the social support quartiles, $F(3,1478) = 1.81$, $p = .14$, but there were significant between-quartile differences in psychological distress, $F(3,1478) = 61.89$, $p < .001$, collapsed across all time points. Women with relatively higher levels of effective social support had lower psychological distress scores compared to women with lower levels of effective social support.

Biobehavioral Coherence between Psychological Distress and Cortisol

In multilevel regression analysis, there was a positive association between psychological distress and cortisol, $\beta = .023$, $p < .001$, after adjusting for time of day and gestational age effects (Model 1 of Table 2). Because the psychological distress variable was person centered, this effect indicates that, for each unit increase in psychological distress above the individual's mean level, there was a corresponding 2.4% increase in cortisol. Across the range of psychological distress values observed in the present study, this effect could result in an overall change in cortisol up to 28.8%. Advancing gestation was associated with a significant increase in the overall level of

cortisol, $\beta = .12$, $p < .001$, but gestational age did not alter the diurnal course of cortisol (see Table 2 Model 1). As reported previously (30), gestational age did not alter the within-person association between psychological distress and cortisol, suggesting that the effects of psychological distress on cortisol are constant over the course of pregnancy.

Effects of Total Social Support

We next added the total score from the SSE to the level-3 submodel to test the hypothesis that social support moderates the within-person association between psychological distress and cortisol. As shown in Model 2 of Table 2, total social support did moderate the association between psychological distress and cortisol, $\beta = -.001$, $p = .039$. As predicted by the buffering hypothesis, effective social support weakened the within-person association between psychological distress and cortisol, resulting in little variation of cortisol across different levels of psychological distress. In contrast, cortisol in women who reported receiving relatively less effective support showed strong within-person increases in concert with increases in psychological distress (see Figure 1). Based upon the range of social support scores observed in this study, the effect of social support for women with the most effective social support was a 50.4% reduction in the mean effect of distress on cortisol and a 2.3 fold increase in this effect for women with the least effective social support.

Discussion

The primary finding of this study was that a perception of effective romantic partner support among pregnant women reduces biobehavioral coherence between psychological distress and cortisol within ecologically relevant situations. As predicted by the buffering hypothesis, women who perceived support as less effective displayed pronounced increases in cortisol when psychological distress increased, whereas women who perceived support as more effective had

low levels of cortisol across the range of negative emotional experience. These data are consistent with the notion that social support buffers the effects of psychological distress on the maternal HPA axis during pregnancy.

These findings are also consistent with laboratory studies in non-pregnant adults that have demonstrated that social support reduces psychophysiological response to standardized acute stressors, even without the physical presence of the supportive partner (49), and extend laboratory-based findings that social support moderates biobehavioral coherence within the context of everyday life. The means by which social support may alter the relationship between psychological and physiological processes have been investigated by Eisenberger and colleagues (50), who propose that social support may alter HPA axis responses by modulating long-term reactivity to social threat in neural regions activated by distressing social separations (e.g., the dorsal region of the anterior cingulate cortex and Brodmann's area 8). Such changes may indicate an epigenetic mechanism by which social experience alters the function of biological systems over time.

The notion that mental representations of social support have an organizational influence on biobehavioral processes is also consistent with findings within attachment literature. During periods of separation from their mothers, securely attached infants may demonstrate psychological distress (e.g., crying) but little or no HPA axis activation (51, 52). Because affective signaling is a useful means for securely attached infants to solicit succor, the infant's expectation of a sensitive and timely response from a dependable caregiver may obviate the need to mount a robust physiological response.

As expected, pregnant women who received higher levels of effective support experienced, on average, less psychological distress than those with relatively less effective

support. This finding is consistent with the notion that socially supported adults appraise their everyday experiences as less threatening and more controllable than unsupported adults (53, 54). In the current analysis, decreases in mean levels of distress are statistically independent of the observed change in biobehavioral coherence because the multilevel model accounts for the fact that individuals have different average levels of psychological distress over time and because the psychological distress variable was mean centered. Accordingly, the parameter estimate for psychological distress within the multilevel model assesses the degree to which deviations from the individual's mean level of psychological distress were associated with changes in cortisol, after accounting for between-person differences in the average level of psychological distress. Research by Mauss and colleagues (37) found that the intensity of negative emotions was not associated with coherence between behavioral and physiological measures, suggesting that the intensity of psychological distress in the current study should not affect coherence.

Within the pregnancy literature, a major focus of studies assessing the effects of psychological experiences on obstetric, birth, and developmental outcomes has centered on plausible biological mechanisms that may transduce maternal experiences of psychological distress into salient developmental signals with the ability to organize growth and elaboration of placental and fetal structures (for reviews see 9, 11, 14). A central hypothesis in the literature is that perceived stress leads to increased levels of maternal cortisol, which may pass through the placental barrier and influence fetal brain development. Although some endogenous maternal cortisol is essential for normal fetal development (21, 22), excess cortisol exposure may impair normal development of the fetal HPA axis and lead to dysregulation of the neuroendocrine stress response (55, 56). Such 'developmental programming' may have enduring functional

consequences for the physical, emotional, and behavioral development of offspring that persists across the lifespan (55, 57).

Individual differences in protective factors, such as effective social support, may help explain why infants exposed to similar levels of maternal psychological distress during gestation may nevertheless have different developmental outcomes (58). Despite widespread acceptance of the notion that social support mitigates the effects of psychological distress (8), few studies have examined the biological mechanisms through which this protective effect occurs during pregnancy (59). The current study supports the proposal that a reduction in biobehavioral coherence between distress and cortisol is a plausible biological mechanism by which effective social support promotes healthy fetal development.

It is important to note that physiological responses to stress are, in themselves, 'protective' mechanisms with well recognized survival value. Failure to mount an appropriate HPA axis response subsequent to perception of threat (i.e., a lack of biobehavioral coherence) may leave an individual vulnerable to injury or death. Nevertheless, a large literature under the rubric of allostatic load has convincingly demonstrated that repeated and prolonged activation of the HPA axis (despite any immediate survival benefit it may have) alters long-term health trajectories. Under everyday conditions of challenge and stress, failure to mount an HPA axis response to perceived threat or stress (i.e., a lack of biobehavioral coherence) may be beneficial. In the context of pregnancy, a 'disruption' of the coherence between cortisol and psychological distress via effective social support could be seen as a protective factor and, in this case, a lack of coherence may benefit the fetus.

The objective of this study was to expand upon social support theory by examining the effect of social support during pregnancy on biobehavioral coherence within ecologically

relevant contexts. To our knowledge, the current study is the first to provide evidence for the biological mechanisms through which this buffering effect occurs during pregnancy. Furthermore, our prospective assessment of momentary psychological experience within ecologically relevant contexts throughout pregnancy is a unique and significant strength. Nevertheless, caution should be exercised when interpreting the results given our sample, which consisted mainly of women without complicated pregnancies, who reported a relatively high socioeconomic status, and who were White. We also did not enroll women who consumed tobacco, streets drugs, or alcohol during pregnancy. These exclusions may have somewhat reduced the observed effects because women with the least effective social support (in the general population) tend to also engage in poor health behaviors (60, 61).

It is important to also note that this study focused exclusively on romantic partner support. Though this type of support is thought to be one of the most significant sources of support during adulthood and particularly during pregnancy (8), it is only one important source during the prenatal period (62). Within the current sample, the romantic partner is likely the most salient potential source of support, but other sources may have greater importance in other cultural contexts (7, 10). Furthermore, the measure used to assess social support includes both positive (emotional, informational, and task) and negative aspects of support. Although both are important to determining support effectiveness, negative support itself could be construed as a stressor. As a result, we cannot unequivocally conclude that social support itself, as opposed to a combination of support and social stress, was responsible for the result. Studies using other measures of support are needed to strengthen the conclusion that social support reduces biobehavioral coherence between psychological and physiological systems during pregnancy.

In summary, this study supports the notion that effective social support alters biobehavioral coherence in pregnant women and suggests that reduced stimulation of cortisol secretion may be a mechanism whereby social support buffers the effects of psychological distress on fetal development. These findings provide a basis for further investigation of the protective role of social support during pregnancy against the developmental sequelae of psychological distress by reducing exposure to maternal cortisol and, thus, the developmental programming effects of maternal distress (e.g., behavioral and neurodevelopmental morbidity). Given that perceived social support is a potentially modifiable intervention target, this study also provides valuable information for future prenatal intervention research.

Table Legends

Table 1a. Descriptive Statistics for Study Variables by Social Support Quartile during First Trimester

Table 1b. Descriptive Statistics for Study Variables by Social Support Quartile during Second Trimester

Table 1c. Descriptive Statistics for Study Variables by Social Support Quartile during Third Trimester

Table 2. Multilevel Models for Within-Person Covariation between Psychological Distress and Cortisol Adjusted for Gestational Age (Model 1), and Effects of Total Social Support (Model 2)

Figure Caption

Figure 1. Within-person association between psychological distress and cortisol as a function of social support

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Table 1a

Descriptive Statistics for Study Variables by Social Support Quartile during First Trimester

	1st Quartile		2nd Quartile		3rd Quartile		4th Quartile	
Variables	**Mean(SD)**	**Range**	**Mean(SD)**	**Range**	**Mean(SD)**	**Range**	**Mean(SD)**	**Range**
Social Support	42.95(8.56)	29-54	58.52(2.11)	55-62	66.00(1.93)	63-69	73.57(2.85)	70-80
Raw Cortisol (ug/dL)								
Waking	.42 (.14)	.17- .71	.45 (.19)	.21-1.00	.38 (.14)	.14-.77	.34 (.16)	.09-.72
Waking + 30 minutes	.44 (.13)	.24- .78	.58 (.26)	.12- 1.20	.47 (.16)	.20-.82	.40 (.19)	.15-1.04
Mid-morning	.19 (.15)	.07-.72	.19 (.08)	.08-.43	.21 (.14)	.07-.81	.18 (.07)	.07-.42
Mid-afternoon	.13 (.07)	.07-.43	.13 (.05)	.05-.26	.12 (.07)	.05-.43	.13 (.07)	.06-.38
Evening	.08 (.04)	.04-.23	.09 (.04)	.03-.25	.07(.03)	.02-.15	.06(.03)	.02-.14
Psychological Distress								
Waking + 30 minutes	4.17 (1.80)	2.13-8.87	3.31 (1.95)	.33-7.27	2.77 (1.66)	.00-6.67	2.63 (1.53)	-.33-6.07
Mid-morning	3.57 (2.16)	.00-9.47	2.86 (2.07)	.00-10.80	2.61 (1.53)	.07-6.73	2.52 (1.72)	-.67-7.27
Mid-afternoon	3.73 (2.09)	-.33- 8.07	3.39 (2.29)	-.33-10.07	3.20 (1.70)	1.00-8.47	2.59 (1.61)	-.33-6.00
Evening	4.3 (1.9)	1.67-8.60	4.09(2.87)	.33-12.53	2.85(1.42)	.33-7.33	3.10(2.38)	-1.00-8.73

Note: Raw cortisol values are presented for descriptive purposes but log transformed values were used in all analyses.

Table 1b

Descriptive Statistics for Study Variables by Social Support Quartile during Second Trimester

	1st Quartile		2nd Quartile		3rd Quartile		4th Quartile	
Variables	**Mean(SD)**	**Range**	**Mean(SD)**	**Range**	**Mean(SD)**	**Range**	**Mean(SD)**	**Range**
Social Support	43.67(9.01)	17-52	59.59(2.32)	53-62	67.53(1.50)	64-69	74.64(4.14)	70-80
Raw Cortisol (ug/dL)								
Waking	.53(.23)	.14-1.16	.52(.15)	.24-.52	.48(.15)	.26-.82	.48(.15)	.22-.80
Waking + 30 minutes	.56(.28)	.18-1.25	.58(.19)	.30-1.03	.59(.22)	.26-1.25	.51(.16)	.27-.98
Mid-morning	.19(.09)	.03-.43	.20(.06)	.11-.31	.24(.14)	.12-.80	.25(.10)	.13-.46
Mid-afternoon	.14(.05)	.07-.31	.16(.06)	.09-.29	.16(.07)	.07-.16	.16(.11)	.06-.56
Evening	.09(.05)	.03-.27	.09(.03)	.05-.19	.08(.03)	.02-.15	.08(.03)	.04-.15
Psychological Distress								
Waking + 30 minutes	3.97 (1.71)	.33-8.20	3.27(1.43)	.33-6.07	2.28(1.46)	-.13-6.60	1.65(1.36)	.00-4.27
Mid-morning	3.81(2.54)	.33-11.93	3.19(1.77)	.73-7.53	1.96(1.30)	.00-6.13	1.63(1.28)	-.33-4.67
Mid-afternoon	4.10(1.83)	1.00-8.40	3.49(1.85)	1.00-8.13	2.52(1.83)	.00-9.27	1.96(1.57)	.00-5.47
Evening	4.85(2.16)	.03-.27	3.36(1.60)	.05-.19	2.51(1.20)	.02-.15	1.94(1.42)	.04-.15

Note: Raw cortisol values are presented for descriptive purposes but log transformed values were used in all analyses.

Table 1c

Descriptive Statistics for Study Variables by Social Support Quartile during Third Trimester

	1st Quartile		2nd Quartile		3rd Quartile		4th Quartile	
Variables	**Mean(SD)**	**Range**	**Mean(SD)**	**Range**	**Mean(SD)**	**Range**	**Mean(SD)**	**Range**
Social Support	46.12(7.33)	25-54	58.89(2.40)	55-63	65.78(1.59)	64-68	73.47(4.27)	69-80
Raw Cortisol (ug/dL)								
Waking	.52(.15)	.30-.95	.49(.14)	.18-.74	.47(.22)	.09-1.12	.48(.19)	.18-.91
Waking + 30 minutes	.59(.19)	.34-1.02	.62(.21)	.29-1.06	.67(.26)	.31-1.25	.59(.19)	.31-1.25
Mid-morning	.29(.15)	.14-.86	.29(.07)	.17-.43	.37(.23)	.18-1.25	.36(.13)	.15-.59
Mid-afternoon	.21(.10)	.07-.57	.21(.04)	.14-.31	.23(.11)	.09-.71	.23(.10)	.07-.51
Evening	.13(.07)	.07-.42	.14(.04)	.07-.22	.12(.05)	.06-.29	.13(.05)	.07-.25
Psychological Distress								
Waking + 30 minutes	3.60(1.87)	.87-7.80	3.93(2.97)	.00-11.07	3.18(1.12)	1.00-5.67	2.68(1.84)	-.47-5.60
Mid-morning	4.13(2.40)	1.00-9.53	3.60(2.61)	.33-11.13	3.25(1.55)	.67-7.73	2.61(1.70)	-.33-5.67
Mid-afternoon	4.86(2.51)	.40-9.40	3.55(2.07)	.67-7.47	3.17(1.83)	.00-9.13	2.04(1.64)	-.33-6.53
Evening	5.06(2.31)	1.20-10.93	4.34(2.15)	1.00-10.93	3.73(1.85)	.00-7.47	2.80(1.49)	.00-6.93

Note: Raw cortisol values are presented for descriptive purposes but log transformed values were used in all analyses.

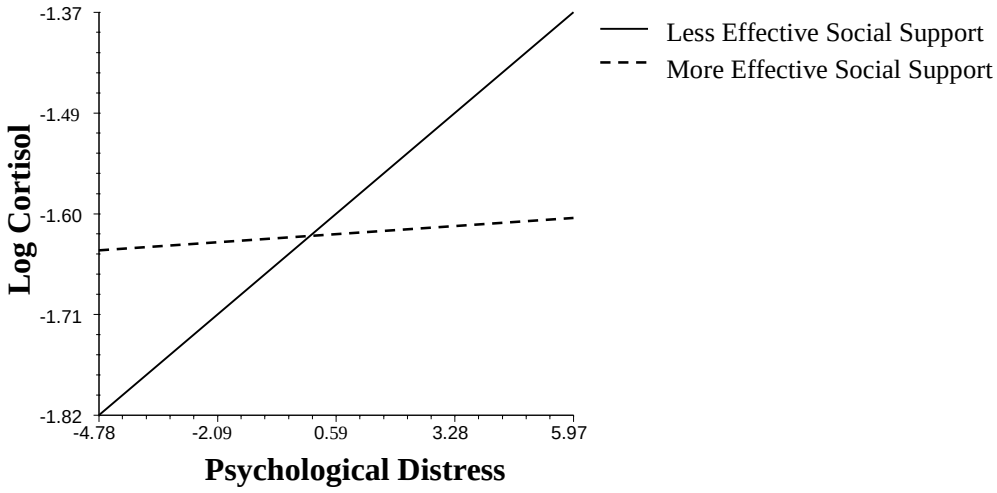
Table 2

Multilevel Models for Within-Person Covariation between Psychological Distress and Cortisol Adjusted for Gestational Age (Model 1), and Effects of Total Social Support (Model 2)

	Model 1			Model 2		
Fixed Effects	Estimate(SE)	t-ratio	p	Estimate (SE)	t-ratio	p
WAKING Levels (π_{0jk})	-1.61(.02)	65.04	<.001	-1.61(.02)	64.86	<.001
Gestational Age	.12(.01)	12.21	<.001	.10(.008)	12.50	<.001
CAR (π_{1jk})	.31(.06)	5.67	<.001	.32(.06)	5.74	<.001
Gestational Age	-.03(.02)	1.31	.19			
TIME (π_{2jk})	-.12(.007)	18.30	<.001	-.12(.007)	18.60	<.001
Gestational Age	.003(.003)	1.09	.28			
$TIME^2$ (π_{3jk})	.003(.001)	2.84	.006	.003(.0009)	3.06	.003
Gestational Age	-.0004(.0004)	1.04	.30			
PSYCHOLOGICAL DISTRESS (π_{4jk})	.023(.007)	3.32	.001	.019(.007)	2.71	.008
Gestational Age	.004(.004)	.99	.32			
Total Social Support				-.001(.0005)	2.10	.039

Note: Estimates are presented for the final most parsimonious models. Words in capital letters indicate time-varying (Level 1) variables. CAR = cortisol awakening response; SE = standard error.

Figure 1. Within-person association between psychological distress and cortisol as a function of social support



Note: More Effective Social Support = mean of upper quartile; Less Effective Social Support = mean of lower quartile