

**Cortisol linkage, stress and perceived partner responsiveness across the transition to parenthood**

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Part of the data and of original findings were part of doctoral dissertation completed by Richter (2022) and were presented at the Conference of the International Society for Research on Emotions (2024), 11<sup>th</sup> European society of Family relations (2023), 17<sup>th</sup> Conference of the Swiss Psychological Society (2022) and International Association for Relationship Research Virtual Conference (2022). We have no conflict of interests to disclose. The study was not pre-registered. This project has received funding from the Swiss National Science Foundation (Grant 100014\_175620) awarded to Dominik Schoebi.

Supplemental materials can be found online: <https://doi.org/10.1037/fam0001419.supp>.

Materials and analysis code are available by emailing the corresponding author.

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**Abstract**

Within a relationship, stress might be shared and co-regulated between the partners at the physiological level, through cortisol linkage. Cortisol is sensitive to social inputs, and cortisol linkage may reflect stress-related dynamics in a couple or positive relational processes, such as marital distress or shared moments. For many couples, the transition to parenthood is accompanied by acute or chronic stressors that can impact the relationship. Concurrently, having a supportive and responsive partner becomes an important resource to adapt to the manifold changes. These relational processes may also play a role with respect to cortisol linkage. The current article reports a study that examined changes of cortisol linkage across the transition to parenthood, and whether high levels of psychological stress and perceived partner responsiveness were associated with stronger cortisol linkage. We used data from a longitudinal study of 120 couples ( $N = 240$ ) who transitioned to parenthood. Participants collected saliva samples and completed an ecological momentary assessment over three consecutive days, during pregnancy, at six months and at 18 months postpartum. Cortisol linkage among partners was significant and positive, increased in strength from pregnancy to six months postpartum, and remained stable from six months to 18 months postpartum. Within-couples, higher levels of psychological stress were associated with a stronger linkage between partners, while higher perceived partner responsiveness was associated with a weaker cortisol linkage. These findings provide further evidence of cortisol linkage during the transition to parenthood, and its associations with positive and negative relational processes.

**Keywords:** cortisol linkage, romantic relationships, psychological stress, perceived partner responsiveness, transition to parenthood

The transition to parenthood can be a stressful period for couples (Saxbe et al., 2018). Although the birth of a first child is broadly regarded as a positive event and life-changing for the parents and their relationship, this transition may also exert considerable stress for both partners (Cowan & Cowan, 1995). Within a relationship, partners are attuned to each other's emotions and moods, which serve to maintain a certain homeostasis and promote change (Butler, 2011; Sbarra & Hazan, 2008). A growing body of research suggests that stress is shared, leading to covariation of stress markers at the physiological level, such as cortisol (Butler, 2011; Levenson & Gottman, 1983). While this physiological linkage is documented in the literature, it remains less clear to what extent associations between partners' momentary cortisol levels are reflections of adaptive or maladaptive relational processes, common stressors, or rather emerge in specific contexts (Timmons et al., 2015).

The transition to parenthood is accompanied by a range of positive as well as negative relational experiences. Unique moments of joy and positive emotions were found to have a beneficial effect on relationship outcomes and relational adjustment. Conversely, an increase in responsibilities and changes leads to elevated stress levels in parents, potentially compromising the intimate relationship (e.g., Kluwer, 2010). These relational experiences could contribute to cortisol linkage between partners. Indeed, stronger cortisol linkage has been associated with negative relationship processes, such as hostility, marital dissatisfaction or negative mood (Liu et al., 2013; Saxbe & Repetti, 2010; Schneiderman et al., 2014), or psychological stress (Braren et al., 2020). It is therefore possible that cortisol linkage increases in strength when a couple becomes parents, as a function of the challenges and stress they face during this new situation. In addition, with the birth of the first child, partners may become more dependent on each other needing more attention and support from each (Dooley et al.,

2018). This could further strengthen the physiological linkage between them. Perceiving a partner to be responsive to one's needs promotes reciprocal responsiveness and fosters emotional closeness and connectedness (Arican-Dinc & Gable, 2023; Reis & Gable, 2015), which has been shown to be associated with stronger physiological linkage (Papp et al., 2013; Timmons et al., 2015, 2023). Consequently, both stress and perceived partner responsiveness may strengthen cortisol linkage between partners.

The present study investigates cortisol linkage between partners and examines whether the strength of cortisol associations between partners increases across the transition to parenthood. Furthermore, we test whether cortisol linkage increases as a function of psychological stress and perceived partner responsiveness.

### **Cortisol linkage in romantic relationships**

Romantic relationships are among the closest social bonds that individuals form in life and intimate partners are often highly interdependent in their daily goals and emotions (Schoebi & Randall, 2015). They engage in frequent daily interactions, care for each other, coordinate their tasks and activities, and include the partner in their plans and goals (Reis, 2020). As a result, their mental and physical states become highly contingent (Pauly et al., 2020; Saxbe & Repetti, 2010).

Covariation of mental and physiological states emerge from the mutual and bidirectional influence of the two partners' states, which can be stable or changing over time (Butler, 2011). For instance, in close relationships, emotions are transmitted or reciprocated between partners, thereby altering their emotional states over time (Butler, 2011). Presumably, this process, which has been described in the literature using various labels, such as coregulation, synchrony, covariation or linkage, serves the maintenance of homeostasis in the relationship and the promotion of adaptation (Butler, 2011; Sbarra & Hazan, 2008). The same process might also

be reflected in the linkage of physiological states between partners (Levenson & Gottman, 1983; Saxbe & Repetti, 2010). In the present study, we examine synchrony, or concurrent covariation of momentary cortisol, which refers to the within-couple between-partner covariance around an assumed stable level (Butler, 2011). Sbarra & Hazan (2008) have discussed how partners up-or down-regulate each other and pointed to the possibility of increased levels of stress when there is a lack of synchrony between them. Partners' psychological and physiological stress becomes shared with their significant other through a reciprocal feedback process (Butler, 2011), and it can reflect dysregulation dynamic, such as when partners reciprocate negative affect (Levenson & Gottman, 1983), and find themselves entrapped in reciprocal cycles of negativity (Butler, 2011). Conversely, partners' synchrony may also contribute to stability in the relationship (Butler, 2011). Physiological linkage may therefore point to important processes at the core of relationship functioning (Meyer & Sledge, 2020).

Several studies have investigated within-relationship associations of the hypothalamic-pituitary-adrenal (HPA) axis activity, as the end product of the HPA axis activity, cortisol output, is considered an objective marker of stress (Laws et al., 2015; Saxbe & Repetti, 2010). Cortisol levels are specifically reactive to threat, challenges and also social cues (Saxbe & Repetti, 2010), and examining cortisol variation allows for the assessment of objective stress related to relationship processes (Meyer & Sledge, 2020). Evidence suggests that romantic partners' diurnal cortisol rhythms are interconnected (Pauly et al., 2020; Saxbe & Repetti, 2010; Timmons et al., 2015). On the one hand, studies have investigated cortisol output and linkage in diurnal rhythms in response to specific situations, such as conflict between partners, in interaction paradigms (Khaled et al., 2021). On the other hand, studies in more naturalistic settings make it possible to track cortisol changes across hours and days in real-life situations, and to study its correlates in couples' daily lives (Braren et al., 2020, 2021; Saxbe & Repetti,

2010). These studies provide insight into the everyday interpersonal processes that may contribute to associations of diurnal cortisol fluctuations between two romantic partners. But clear and consistent evidence for cortisol linkage that points to specific relational processes and relationship functioning is sparse. Periods in which relationships face major challenges that require adaptation, such as the transition to parenthood, may offer a unique window to study relational correlates of cortisol linkage.

### **Transition to parenthood and cortisol linkage**

The birth of a first child is a major life event that brings new challenges and changes for the parents and their relationship (Edelstein et al., 2015). This transition is often associated with sleep disruptions and psychosocial stress, and an increased risk to develop psychological and physical health problems (Saxbe et al., 2018). After birth, conflicts and anxiety become more common, and in some couples, relationship satisfaction declines (Figueiredo et al., 2008; Lawrence et al., 2007). Moreover, after the birth of the child, when both partners experience stress more often, it becomes more likely that a stress experience of one partner crosses over to and affects the other partner (Cowan & Cowan, 1995). These profound changes in the relationship might also be observed at the physiological level, through cortisol linkage.

To date, many studies document prenatal cortisol linkage between partners, using either data from blood samples (Berg & Wynne-Edwards, 2002; Storey et al., 2000) or salivary cortisol (Berg & Wynne-Edwards, 2002; Braren et al., 2020; Edelstein et al., 2015; Khaled et al., 2021). At postpartum, one study found limited evidence for cortisol linkage between mothers and fathers, based on blood samples (Berg & Wynne-Edwards, 2002) but another study found evidence for cortisol linkage two years after the birth of an infant, using salivary cortisol (Saxbe et al., 2015). Findings on associations between relational processes and cortisol linkage remain inconclusive. Several studies reported that stronger cortisol linkage was

associated with poorer relationship functioning, lower marital satisfaction and relationship distress (Laws et al., 2015; Saxbe & Repetti, 2010), more spousal strain and disagreement (Liu et al., 2013), and increased maternal stress during pregnancy (Braren et al., 2020). Yet, some results pointed to an association of cortisol linkage with positive or neutral relationship processes, such as more time spent together (Khaled et al., 2021; Papp et al., 2013; Saxbe & Repetti, 2010) or less negativity in conflicts during pregnancy (Khaled et al., 2021). Based on the available evidence, we would expect that the changes in relationship dynamics and increasing stress between pregnancy and early parenthood will go along with a stronger linkage between partners' cortisol levels (Braren et al., 2020).

### **Moderators of cortisol linkage across the transition to parenthood**

During the transition to parenthood, both positive and negative relational processes are at stake (Kluwer, 2010; Lawrence et al., 2007). Expectant parents may be more susceptible to be closely associated in their physiological responses, and multiple processes might contribute to physiological linkage. Two types of processes might be particularly salient during the transition to parenthood: psychological stress and partner responsiveness.

Expectant parents experience increased psychological stress when faced with the challenges of this transition (Saxbe et al., 2018). Changes in both roles and routines may increase psychological and relationship distress, which has been linked with higher cortisol levels across the day (Hughes et al., 2020). A negative affect reciprocity perspective might suggest that mutually high levels of psychological stress in partners may be accompanied by similar patterns in their physiological states and reflect a reciprocal loop of negativity (Levenson & Gottman, 1983). Consequently, elevated psychological stress in both partners may contribute to a robust cortisol linkage. Braren and colleagues (2020), for example, found that at pregnancy, cortisol linkage was increased when maternal psychological stress was

higher. We therefore expect that higher levels of psychological stress in the partners may contribute to a stronger cortisol linkage between them during the transition to parenthood.

The strain induced by expecting birth and becoming a parent may prompt individuals to seek comfort and support from a partner (Dooley et al., 2018), and it requires responsiveness to a partner's disclosures of needs and concerns to convey a sense of feeling understood, cared for and validated by the partner (Reis & Gable, 2015). Perceiving a partner's responsiveness motivates reciprocation of attention and care, promotes perceptions of support when facing stressful events or chronic stress (Smallen et al., 2021; Ter Kuile et al., 2017) and enhances closeness between partners via interpersonal emotion regulation (Arıcan-Dinc & Gable, 2023). Because relationship distress has been associated with stronger cortisol linkage, it could be expected that high perceived partner responsiveness, reflecting healthy relationship functioning and support, would weaken cortisol linkage, at least when couples are exposed to stressors. Yet, we found no empirical research suggesting associations between perceived partner responsiveness and cortisol linkage, whereas evidence exists for linkage in electrodermal activity when individuals reported feeling emotionally close and connected to their partner (Timmons et al., 2023) or when partners scored higher on empathy traits (Chatel-Goldman et al., 2014). This dovetails with conclusions from a review by Timmons et al. (2015), that pointed to emotional connectedness being associated with cortisol linkage between partners. Therefore, to the extent that perceived partner responsiveness fosters closeness between partners, it may also translate into stronger cortisol linkage between partners.

### **The present study**

The present study aims to enhance our understanding of cortisol linkage between intimate partners during the transition to parenthood. To this end, we assessed within-dyad associations in momentary cortisol levels between partners in 120 couples across the transition to

parenthood, and we examined psychological stress and perceived partner responsiveness as potential moderators of cortisol linkage. We expected positive associations between partners' moment-to-moment cortisol basal levels during pregnancy and at six, and 18 months after birth (hypothesis 1). Moreover, we expected that the strength of these associations between partners would increase from pregnancy to 18 months after birth (hypothesis 2), and we expected this increase to occur as a function of parents' psychological stress levels (hypothesis 3). Because perceiving the partner as responsive enhances closeness between partners, we expected that higher levels of perceived partner responsiveness in parents would also be associated with stronger cortisol linkage between partners (hypothesis 4).

## **Method**

### **Participants**

Inclusion criteria comprised being over 18 years old, living together, speaking fluently either French or German and expecting a first child together. Couples were recruited through gynecologists, midwives and hospitals, flyers, mailing lists, prenatal courses, and word-of-mouth. Each couple received 800.– Swiss Francs (approximately 900 US Dollars) for participation in all parts of the study.

Data from 120 heterosexual couples expecting their first child together ( $N = 240$ ) and having participated in the entire study were used. Mean age for women was 31.6 years old ( $SD = 3.7$ ) and 33.2 years old ( $SD = 4.1$ ) for men. At the time of recruitment, couples reported to be in a relationship on average for 6.7 years ( $SD = 3.6$ ), and all couples lived in Switzerland. Participants reported a relatively high level of education, with 65.6% having a university degree, 11.9% completed another degree of advanced education, 10.3% completed an apprenticeship, 5.6% were students at a higher education institution, and 6.7% completed high

school. On average, 70.9% participants reported being employed, 9.6% of which in an executive function, 10.9% reported being self-employed and 8,6% were not employed.

### **Procedure**

We report below how we determined our sample size, all data exclusions, all manipulations, and all measures in the study. The current study is part of a longitudinal project on transition to parenthood, that started in April 2019 and ended in June 2023. Couples completed assessments at three time points: during the second or third trimester of pregnancy (T1), at 6-months (T2), and 18 months postpartum (T3). The sample size for our analyses was determined by including only couples having completed all time points, as we aimed to examine change in couples' cortisol linkage across time. Therefore, we excluded data from 29 couples ( $N = 58$  participants) that took part only in two time points, yielding a final sample of 120 couples ( $N = 240$ ). The study was approved by the cantonal ethics committee (CER-VD) under the title "Affect regulation, stress response and responsiveness-the impact of challenging conditions on intimate relationships and well-being". This study was not preregistered.

After providing informed consent, all participants were asked to complete an online questionnaire at T1, T2 and T3, which included questions related to both partner's demographics, their relationship and physical and psychological health. Moreover, at each time point, participants were instructed to complete a seven-days ecological momentary assessment, four times a day. In parallel, they were asked to collect saliva samples on three consecutive working days, at four times a day. The duration of sampling is in line with recommendations in the literature that at least a two-day sampling is required to obtain reliable cortisol measurements (Saxbe, 2008). The research assistant answered all questions about the study and the measures and was available by phone if questions arose later. Once the assessment week was completed, participants sent back the material via a pre-paid courier package.

## Measures

*Salivary cortisol measures.* Saliva was sampled at three time of assessment (T1, T2, and T3), and within each time point, during three consecutive days with awakening ( $M = 7:15$  a.m.), at 30 min after awakening ( $M = 7:49$  a.m.), before lunch ( $M = 12:32$  p.m.) and before dinner ( $M = 19:08$  p.m.), using Salivettes (Salivette Cortisol; Sarstedt, Nümbrecht, Germany). Each participant could therefore provide a maximum of 12 cortisol samples within each time of assessment and a maximum of 36 cortisol samples over the three times of assessment. To control for sampling time and influencing factors, participants were instructed not to eat or drink, not to smoke or brush their teeth or to do sport an hour before collecting the saliva samples. Cotton swabs were stored in a plastic bottle assigned to each participant, using the Medication Event Monitoring System (MEMS; AARDEX Ltd.). Participants kept saliva samples in their fridge and sent them back to the lab. All samples were stored at  $-30^{\circ}\text{C}$  in the lab freezer until shipment to the Dresden Lab Service (Dresden, Germany) for analysis. The lab used a commercial chemiluminescence immunoassay and the intra and interassay coefficients for cortisol were both below 7%. Participants provided 97.7 % out of 12 scheduled samples within the three days of assessments at T1, 96.2% at T2, and 94.6 % at T3.

*Covariates.* Participants completed a short protocol at each point of saliva sampling and provided information about drink and food intake, smoking, brushing teeth and physical activity within an hour before saliva sampling (Nicolson, 2008), to reduce the potential influence of these factors. In addition, regular medicine intake, working hours (if participants had night shift) and breastfeeding was assessed at T2 and T3. We also controlled for a second pregnancy (weeks stage) during later assessment points, because several couples reported expecting a second child at the T3 assessment. Finally, data collection (T1 and T2) during the Covid-19 pandemic lockdown was coded as ‘lockdown condition’.

*Perceived partner responsiveness (PPR).* Momentary assessments of perceived partner responsiveness parallel to the cortisol sampling on these three days were used. At each prompt (at 8:00 a.m., noon, 6:00 p.m. and 9:30 p.m.), participants reported with three items whether they perceived their partner to be understanding, validating, and caring, using a 10-point scale ranging from 0 (*not at all*) to 10 (*extremely*). A mean score of the three items was created for the data analyses. Because PPR varied between persons, and within persons across days, both an aggregate score reflecting participants' average PPR, and the daily average were used in the analyses. On average, scores of perceived partner responsiveness over the three days of assessment used were high for both women ( $M = 8.37$ ;  $SD = 1.59$ ) and men ( $M = 8.18$ ;  $SD = 1.65$ ). Internal consistency was high for both women (within:  $\omega = .873$ ; between:  $\omega = .977$ ) and for men (within:  $\omega = .859$ ; between:  $\omega = .986$ ) across the three times of evaluation.

*Psychological stress.* We assessed psychological stress with the Perceived Stress Scale (Cohen et al., 1983). Participants completed the questionnaire at each time point (T1, T2, and T3). The scale included five items reflecting individuals' appraisals of stressful life situations, using a scale from 0 (*never*) to 4 (*very often*). A total score was obtained by summing the answers (ranging from 0 to 20), with higher scores indicating stronger perceptions of stress. Both women and men had relatively low average scores (women:  $M = 7.58$ ;  $SD = 4.00$ ; men:  $M = 6.60$ ;  $SD = 3.77$ ). Internal consistency was high for women ( $\alpha = .848$ ) and for men ( $\alpha = .842$ ) across the three times of evaluation.

### **Statistical analyses**

To analyze the data, we used a multilevel modelling approach (MLM), to accommodate for multiple sources of nonindependence due to repeated measures data across days and within dyads (Bolger & Laurenceau, 2013). The analyses used ML estimation to accommodate missing data and variation in time intervals between repeated measures (Hruschka et al., 2005;

Nicolson, 2008). We used a four-level model to account for all time of measurements. Therefore, repeated measures of individuals' diurnal cortisol levels were nested within days, days were nested within time of assessments across the transition of parenthood, which were nested within dyads. Main analyses were performed with the R package nlme (Pinheiro et al., 2018).

Each participant had cortisol data from four sampling time points per day, for three consecutive days, at T1, T2 and T3, which represents a maximum of 36 samples per participant. Cortisol varied within the three assessment time points (i.e., TTP assessments). We created a partner cortisol variable to use as a predictor variable, which we centered at the daily mean of the participant, such that it reflects variation of the partner's cortisol values around his or her mean cortisol level on a particular day, within an assessment time point (T1, T2, T3). We used this variable to estimate cortisol linkage between partners. This operationalization has been used in prior studies examining cortisol using multilevel modelling (Adam et al., 2006; Saxbe & Repetti, 2010).

Outliers in cortisol data can bias results, therefore all the values smaller or larger than 4 *SD* from the mean cortisol and mean time of collection were dropped (Nicolson, 2008). In addition, because the cortisol awakening response (CAR) is sensitive to time, values were excluded if the time lag between the first and the second samples was smaller than 15 minutes or larger than 60 minutes. Overall, there were 2.77% outliers removed from the data. Because the distribution of cortisol data were skewed, cortisol values were log-transformed prior to statistical analysis (Nicolson, 2008), adding a constant of 1 to the cortisol values before transformation to prevent negative values (West, 2022). To prevent biased results due to unequal variances in men's or women's cortisol values at different assessment time points, and to enhance comparability of estimates across partners and time, we performed a z-transformation for men and for women at each assessment time point (resulting in standardized

data with a mean of 0 and a standard deviation of 1 for men and women at each assessment time point).

Hypothesis 1 predicted that cortisol associations between partners. We estimated separate intercepts for male and female participants, along with the partner's diurnal cortisol variables as predictors. In equation 1,  $Cortisol_{ij}$  represents the cortisol values of each participant  $i$  at sampling time  $j$ . The estimates  $\beta_{0i}$  and  $\beta_{1i}$  represent the mean level of cortisol for female and male, when all other parameters are held constant. The predictors  $wCortp_{ijklm}$  and for  $mCortp_{ijklm}$  represent women's and men's partner cortisol value on day  $k$  of assessment time  $l$  of couple  $m$ , and the coefficients for these parameters capture cortisol linkage between the male and the female partners. It is important to note that these two parameters represent unstandardized estimates of the same linkage. The parameter for  $r_{tm}$  represents the within-couple residual variance at time  $t$  in couple  $m$ .

$$1 \quad Cortisol_{it} = \beta_{0i} + \beta_{1i} + wCortp_{ijklm} + mCortp_{ijklm} + r_{tm}$$

Hypothesis 2 predicted that the associations of cortisol between partners would be stronger from pregnancy to 18 months after birth, and hypothesis 3 predicted that variation of psychological stress across the three measurement times would predict cortisol linkage between partners. Similarly, hypothesis 4 predicted that high levels of perceived partner responsiveness would be associated with a stronger cortisol linkage.

Thus, for hypothesis 2, we extended equation 1 and included two indicators  $t1t2$  and  $t2t3$  to reflect the time lag from T1 to T2 as well as the time lag from T2 to T3. This variable reflected the number of months between each time point. We included two interaction terms, between cortisol levels and *each of the time indicators*. Coefficients for these interaction terms captured whether cortisol associations would grow stronger between T1 and T2, and then between T2 and T3, respectively.

Next, to test hypotheses 3 and 4, we extended model 1 by adding the psychological stress and perceived partner responsiveness variables of both partners, centered at the person mean. These variables captured variability in a person's psychological stress experience and perceived partner responsiveness across the three TTP assessments. To examine associations with cortisol linkage, we added interaction terms of these variables with the partner cortisol variables. To specifically examine effects of perceived partner responsiveness on a particular day, we added daily perceived partner responsiveness to the model, centered at the participant's mean of perceived partner responsiveness ratings across the three days of sampling in a particular assessment period. This variable reflects daily variation in perceptions of partner responsiveness across the three days of assessment time and within each TTP assessment time. Again, interaction terms with partner cortisol were added.

### **Transparency and openness**

Materials and analysis code for this study are available by emailing the corresponding author.

## **Results**

### **Descriptive statistics**

The means and standard deviation of psychological stress and perceived partner responsiveness across days and times of assessment are presented in Table 1 and the corresponding values of cortisol values across sampling time, days, and time of assessment are presented in Table 2. The correlation matrix between the main variables is shown in Table 3.

The time lag between T1 and T2 was on average of 7.7 months ( $SD = .1.35$ ), and the average for the time lag between T2 and T3 was of 11.44 months ( $SD = 1.31$ ). There were no significant differences in psychological stress between men and women at T1 (paired-samples  $t(118) = 1.915, p = .058$ ) and T2 (paired-samples  $t(113) = 1.407, p = .162$ ). At T3, there was a

significant difference between men and women (paired-samples  $t(109) = 2.696, p = .008$ ). There were significant differences in cortisol levels between men and women at T1 (paired-samples  $t(117) = 11.472, p < .001$ ), and at T2 (paired-samples  $t(120) = -2.813, p = .006$ ) but not at T3 (paired-samples  $t(120) = -.941, p = .348$ ). Regarding perceived partner responsiveness, there were significant differences between men and women at T1, (paired-samples  $t(115) = 2.361, p = .020$ ), but not at T2 (paired-samples  $t(110) = .988, p = .235$ ) and at T3 (paired-samples  $t(115) = 1.502, p = .136$ ).

Table 1. Mean and standard deviation of perceived partner responsiveness and psychological stress for women and men, across three days of assessment, at pregnancy, 6 months post-partum and 18 months post-partum

|                                  | Pregnancy |           |          |           | 6 Months Post-Partum |           |          |           | 18 Months Post-Partum |           |          |           |
|----------------------------------|-----------|-----------|----------|-----------|----------------------|-----------|----------|-----------|-----------------------|-----------|----------|-----------|
|                                  | Women     |           | Men      |           | Women                |           | Men      |           | Women                 |           | Men      |           |
|                                  | <i>M</i>  | <i>SD</i> | <i>M</i> | <i>SD</i> | <i>M</i>             | <i>SD</i> | <i>M</i> | <i>SD</i> | <i>M</i>              | <i>SD</i> | <i>M</i> | <i>SD</i> |
| Perceived partner responsiveness | 8.69      | 1.16      | 8.41     | 1.39      | 8.15                 | 1.45      | 8.09     | 1.47      | 8.23                  | 1.34      | 7.97     | 1.55      |
| <i>Day 1</i>                     | 8.79      | 1.39      | 8.43     | 1.49      | 8.24                 | 1.67      | 8.10     | 1.69      | 8.35                  | 1.40      | 8.01     | 1.68      |
| <i>Day 2</i>                     | 8.78      | 1.33      | 8.42     | 1.61      | 8.10                 | 1.71      | 8.14     | 1.73      | 8.23                  | 1.62      | 8.09     | 1.66      |
| <i>Day 3</i>                     | 8.61      | 1.48      | 8.48     | 1.54      | 8.34                 | 1.58      | 8.03     | 1.77      | 8.19                  | 1.52      | 7.96     | 1.72      |
| Psychological stress             | 6.86      | 3.39      | 6.17     | 3.27      | 8.00                 | 4.24      | 7.32     | 4.13      | 7.97                  | 4.45      | 6.53     | 3.93      |

*Note.* N = 240. Psychological stress scores range from 0 to 20.

Table 2. Mean and standard deviation of cortisol values for women and men, across three days of assessment, at pregnancy, 6 months post-partum and 18 months post-partum

|                       | Pregnancy |           |          |           | 6 Months Post-Partum |           |          |           | 18 Months Post-Partum |           |          |           |
|-----------------------|-----------|-----------|----------|-----------|----------------------|-----------|----------|-----------|-----------------------|-----------|----------|-----------|
|                       | Women     |           | Men      |           | Women                |           | Men      |           | Women                 |           | Men      |           |
|                       | <i>M</i>  | <i>SD</i> | <i>M</i> | <i>SD</i> | <i>M</i>             | <i>SD</i> | <i>M</i> | <i>SD</i> | <i>M</i>              | <i>SD</i> | <i>M</i> | <i>SD</i> |
| <i>Cortisol Day 1</i> |           |           |          |           |                      |           |          |           |                       |           |          |           |
| Awakening             | 10.01     | 4.00      | 7.93     | 3.87      | 7.22                 | 4.02      | 8.26     | 4.22      | 7.52                  | 3.67      | 7.30     | 4.13      |
| Awakening + 30 min    | 13.42     | 4.34      | 10.57    | 4.59      | 8.62                 | 5.46      | 9.21     | 5.27      | 8.95                  | 5.12      | 9.74     | 5.42      |
| Before lunch          | 5.92      | 2.59      | 2.83     | 1.76      | 2.29                 | 1.35      | 3.06     | 2.09      | 2.82                  | 1.84      | 2.78     | 2.44      |
| Before dinner         | 2.73      | 1.30      | 1.29     | 1.67      | 0.94                 | 0.89      | 0.96     | 0.87      | 1.16                  | 1.19      | 1.10     | 2.01      |
| <i>Cortisol Day 2</i> |           |           |          |           |                      |           |          |           |                       |           |          |           |
| Awakening             | 9.80      | 3.76      | 7.51     | 3.53      | 6.83                 | 3.91      | 7.87     | 4.04      | 7.46                  | 3.94      | 7.29     | 4.11      |
| Awakening + 30 min    | 12.44     | 4.46      | 10.23    | 5.09      | 7.75                 | 4.81      | 8.61     | 5.19      | 8.46                  | 5.02      | 9.06     | 5.41      |
| Before lunch          | 5.98      | 2.13      | 2.89     | 2.08      | 2.30                 | 1.45      | 2.46     | 1.63      | 2.69                  | 1.88      | 2.84     | 2.34      |
| Before dinner         | 2.92      | 2.02      | 0.98     | 0.76      | 1.04                 | 2.00      | 0.86     | 0.65      | 1.38                  | 1.48      | 1.28     | 2.07      |
| <i>Cortisol Day 3</i> |           |           |          |           |                      |           |          |           |                       |           |          |           |
| Awakening             | 10.07     | 3.82      | 7.84     | 3.49      | 7.02                 | 4.13      | 7.99     | 4.37      | 7.17                  | 3.59      | 7.83     | 4.28      |
| Awakening + 30 min    | 11.78     | 3.83      | 9.63     | 4.28      | 7.87                 | 4.69      | 9.32     | 5.26      | 8.96                  | 5.31      | 8.94     | 5.30      |
| Before lunch          | 6.13      | 2.28      | 2.55     | 1.77      | 2.23                 | 1.71      | 2.66     | 2.17      | 4.01                  | 2.10      | 2.96     | 2.67      |
| Before dinner         | 2.88      | 1.20      | 1.18     | 1.50      | 1.09                 | 1.76      | 0.93     | 1.26      | 1.27                  | 1.02      | 1.26     | 1.45      |

*Note.* N = 240. Data presented are raw cortisol values (i.e. not log-transformed).

Table 3. Correlation matrix for psychological stress and perceived partner responsiveness, at pregnancy, 6 and 18 months after birth for men and women

|                  | 1.     | 2.      | 3.    | 4.      | 5.      | 6.      | 7.     | 8.     | 9.     | 10.    | 11.    | 12. |
|------------------|--------|---------|-------|---------|---------|---------|--------|--------|--------|--------|--------|-----|
| 1. PSS T1 women  | —      |         |       |         |         |         |        |        |        |        |        |     |
| 2. PSS T1 men    | .371** | —       |       |         |         |         |        |        |        |        |        |     |
| 3. PSS T2 women  | .399** | .470**  | —     |         |         |         |        |        |        |        |        |     |
| 4. PSS T2 men    | .193*  | .057    | .013  | —       |         |         |        |        |        |        |        |     |
| 5. PSS T3 women  | .149   | .271**  | .076  | .472**  | —       |         |        |        |        |        |        |     |
| 6. PSS T3 men    | .141   | .242*   | .197* | .534**  | .598**  | —       |        |        |        |        |        |     |
| 7. PPR T1 women  | -.160  | -.053   | -.046 | -.289** | -.340** | -.275** | —      |        |        |        |        |     |
| 8. PPR T1 men    | -.164  | -.071   | -.086 | -.446** | -.413** | -.416** | .455** | —      |        |        |        |     |
| 9. PPR T2 women  | -.154  | -.211*  | -.043 | -.063   | -.200*  | -.206*  | .562** | .234*  | —      |        |        |     |
| 10. PPR T2 men   | -.192* | -.248** | -.044 | -.367** | -.466** | -.413** | .460** | .724** | .498** | —      |        |     |
| 11. PPR T3 women | -.135  | -.105   | .039  | -.124   | -.330** | -.204*  | .656** | .342** | .474** | .427** | —      |     |
| 12. PPR T3 men   | -.165  | -.150   | -.021 | -.365** | -.535** | -.535** | .409** | .696** | .425** | .817** | .466** | —   |

*Note.* \*\*\*  $p < .001$ , \*\*  $p < .01$ , \*  $p < .05$ . PSS = Perceived Stress Scale; PPR = Perceived Partner Responsiveness; T1 = pregnancy; T2 = 6 months after birth; T3 = 18 months after birth

### **Couples' cortisol linkage and associations across the transition to parenthood**

We predicted that men's and women's cortisol levels would be positively associated with each other across the three points (hypothesis 1). The results suggest that cortisol levels of men and women were associated across momentary measurements (when using women's cortisol as dependent variable:  $b = .352, p < .001$ ; when using men's cortisol as dependent variable:  $b = .319, p < .001$ ; these unstandardized coefficients reflect the same dyadic association, but differ slightly due to differences in within-subject variances between the two partners). In this analysis, we controlled for time of sampling, breastfeeding and weeks of pregnancy at T1 and at T3 (potential confounding variables having nightshift, being in lockdown, taking medicine, exercising, smoking, eating or drinking and brushing teeth were not significant and were therefore not included in the final model). The full results including the coefficients for significant confounders can be found in the supplemental materials.

Next, we tested whether the strength of the linkage between men's and women's cortisol levels increased across the transition to parenthood, from pregnancy to 6 months postpartum to 18 months postpartum (hypothesis 2). As shown in Table 4, the data suggest that from pregnancy to six months after birth, a moderate yet statistically significant increase in cortisol linkage occurred (when using women's cortisol as dependent variable:  $b = .002, p < .001$ ; when using men's cortisol as dependent variable:  $b = .009, p < .001$ ). We found no significant difference in the strength of cortisol linkage from six months to 18 months after birth.

Table 4. Cortisol linkage and changes from pregnancy to 6 months postpartum and from 6 to 18 months postpartum

|                                     | Cortisol |             |           |           |          |
|-------------------------------------|----------|-------------|-----------|-----------|----------|
|                                     | <i>b</i> | <i>S.E.</i> | <i>LL</i> | <i>UL</i> | <i>p</i> |
| Intercept women                     | .642     | .017        | .601      | .675      | <.001    |
| Intercept men                       | .642     | .012        | .618      | .666      | <.001    |
| Women's partner cortisol            | .342     | .003        | .335      | .348      | <.001    |
| Men's partner cortisol              | .360     | .003        | .353      | .366      | <.001    |
| Pr-6pp W                            | -.028    | .002        | -.033     | -.023     | <.001    |
| 6pp-18pp W                          | .001     | .002        | -.002     | .004      | .347     |
| Pr-6pp M                            | -.005    | .002        | -.008     | -.001     | .007**   |
| 6pp-18pp M                          | .001     | .001        | -.002     | .003      | .584     |
| Women's partner cortisol x Pr-6pp   | .009     | .001        | .008      | .010      | <.001    |
| Women's partner cortisol x 6pp-18pp | .001     | .001        | -.001     | .001      | .458     |
| Men's partner cortisol x Pr-6pp     | .002     | .001        | .002      | .003      | <.001    |
| Men's partner cortisol x 6pp-18pp   | .001     | .001        | -.001     | .001      | .688     |

*Note.* \*\*\*  $p < .001$ , \*\*  $p < .01$ , \*  $p < .05$ . M = men; W = women; Pr-6pp = time indicator between pregnancy and 6 months after birth in months; pr-18pp = time indicator between 6 and 18 months after birth in months.

### Couples' cortisol associations and psychological stress

Our hypothesis 3 proposed that the strength of the linkage between partners' cortisol levels would be stronger at higher psychological stress of the partners. The results confirmed an association of women's psychological stress and stronger cortisol linkage when using women's cortisol as dependent variable ( $b = .003$ ,  $p < .001$ ), but not men's psychological stress and cortisol linkage when using men's cortisol as dependent variable ( $b = .001$ ,  $p = .186$ ).

Table 5. Moderations effects of psychological stress and perceived partner responsiveness on cortisol linkage

|                                        | Cortisol |             |           |           |          |
|----------------------------------------|----------|-------------|-----------|-----------|----------|
|                                        | <i>b</i> | <i>S.E.</i> | <i>LL</i> | <i>UL</i> | <i>p</i> |
| Intercept women                        | .754     | .011        | .733      | .774      | <.001    |
| Cortisol men                           | .656     | .010        | .638      | .675      | <.001    |
| Women's partner cortisol               | .316     | .003        | .310      | .321      | <.001    |
| Men's partner cortisol                 | .352     | .003        | .347      | .358      | <.001    |
| Psychological stress W                 | -.007    | .003        | -.012     | -.001     | .022*    |
| Psychological stress M                 | -.001    | .003        | -.007     | .004      | .613     |
| Women's partner cortisol x PSS W       | .003     | .001        | .002      | .004      | <.001    |
| Men's partner cortisol x PSS M         | .001     | .001        | -.001     | .003      | .186     |
| Perceived partner responsiveness W     | .035     | .022        | .015      | .056      | <.001    |
| Perceived partner responsiveness M     | -.002    | .009        | -.020     | .016      | .825     |
| Women's partner cortisol x PPR W       | -.018    | .003        | -.023     | -.012     | <.001    |
| Men's partner cortisol x PPR M         | -.006    | .003        | -.012     | -.001     | .046*    |
| PPR daily W                            | -.001    | .002        | -.004     | .003      | .853     |
| PPR daily M                            | .001     | .002        | -.003     | .005      | .749     |
| Women's partner cortisol x PPR daily W | -.001    | .002        | -.004     | .004      | .936     |
| Men's partner cortisol x PPR daily M   | -.005    | .002        | -.010     | -.001     | .026*    |

*Note.* \*\*\*  $p < .001$ , \*\*  $p < .01$ , \*  $p < .05$ . M = men; W = women; PPR daily = perceived partner responsiveness centered at the daily level; PPR = perceived partner responsiveness centered at the time of assessment level.

### Couples' cortisol linkage and perceived partner responsiveness

Finally, we expected that higher levels of perceived partner responsiveness would be associated with a stronger cortisol linkage between partners (hypothesis 4). For this hypothesis, we examined perceived responsiveness as generalized reports at the three assessment times, and also at the daily level. Contradicting our hypothesis, women and men's generalized reports of perceived responsiveness at the three assessment times were associated with a weaker linkage (women's perceptions of partner responsiveness:  $b = -.018$ ,  $p < .001$ ; men's perceptions of partner responsiveness:  $b = -.006$ ,  $p < .05$ ). At the daily level, results also suggested that higher levels of men's momentary perceptions of partner responsiveness were associated with

weaker, not stronger cortisol linkage, using men's cortisol as dependent variable ( $b = -.005$ ,  $p = .026$ ). Women's momentary perceptions of partner responsiveness were not significantly associated with cortisol linkage when using women's cortisol as dependent variable ( $b = -.001$ ,  $p = .936$ ). The results are presented in Table 5.

### Discussion

The aim of this study was to examine cortisol linkage between partners across the transition to parenthood and its associations with stress and perceived partner responsiveness. To this end, we investigated whether the time during the transition to parenthood, psychological stress and perceived partner responsiveness were associated with the strength of partners' cortisol linkage. To our knowledge, this is the first study that used a longitudinal design to assess the course of cortisol linkage with diurnal cortisol rhythms over time between new parents, extending beyond previous work by Laws et al., (2015) who used a longitudinal approach to examine cortisol convergence in newlywed couples. The longitudinal design also allowed us to test within-subject moderators of cortisol linkage. Prior studies investigated cortisol linkage at pregnancy (Braren et al., 2020, 2021; Edelstein et al., 2015; Khaled et al., 2021) and one study examined cortisol associations between the two partners, for two years following the birth of their first, second or third child (Saxbe et al., 2015).

We expected that the two partners' cortisol levels were positively associated (hypothesis 1), and that the strength of this association increased across the transition to parenthood (hypothesis 2). The analyses confirmed that partners' cortisol levels were positively associated. At six months after birth, cortisol linkage was stronger than during pregnancy but did not change any further between six months and 18 months after birth. We also expected that cortisol linkage would be stronger at higher psychological stress levels of the partners (hypothesis 3), and at higher levels of perceived partner responsiveness (hypothesis 4).

Hypothesis 3 was partially confirmed, with analyses suggesting a stronger cortisol linkage when women's psychological stress was higher, but men's psychological stress was not significantly related to cortisol linkage. The data did not confirm hypothesis 4, as we found that perceived partner responsiveness was associated with a weaker cortisol linkage rather than the predicted stronger linkage.

### **Cortisol linkage across the transition to parenthood**

The findings of our first hypothesis confirmed the results of prior studies, showing a cortisol linkage between partners overall (Laws et al., 2015; Liu et al., 2013; Saxbe et al., 2015; Saxbe & Repetti, 2010), and also during pregnancy (Braren et al., 2020; Khaled et al., 2021). The current results indicated that, across the transition to parenthood, partners moment-to-moment fluctuations in cortisol output covaried.

Testing associations of cortisol linkage and time across the transition to parenthood partially confirmed hypothesis 2. Cortisol linkage was stronger at six months postpartum than at pregnancy, and it remained constant between six and 18 months after birth. It seems plausible to assume that changes between pregnancy and six months after birth are more marked, both at a physiological level (for the mother in particular; e.g., Berg & Wynne-Edwards, 2002) and with respect to stressors and demands for adjustment, than the phase following the first six months after birth. Indeed, the first months after the birth of a child are often particularly demanding for parents and they need to adjust to these changes. For instance, new parents experience the negative effects of sleep deprivation (Medina et al., 2009), and face the manifold challenges of developing parenting and co-parenting skills (Christopher et al., 2015; Paley & Hajal, 2022). Although parents may then develop a routine adapting to their role as new parents, they continue to face these challenges and have to negotiate and reorganize many aspects of their relationship (Curran et al., 2006), and adapt to getting back to work after their maternity

leave (Staehelin et al., 2007). Parenthood beyond six months is therefore likely to remain demanding, but likely not at a level that is above and beyond that of the first months of parenthood. Partners may also spend more time together as parents than before the birth of the child, which was found to be associated with stronger linkage between partners (Saxbe & Repetti, 2010).

It therefore appears to be less the transition to parenthood per se that is associated with an increase in cortisol linkage, but rather early parenthood more broadly, as compared to pregnancy. Conversely, it may also be that factors related to pregnancy, such as hormonal changes and psychological factors associated with the expected, render pregnancy a period of particularly restricted cortisol linkage.

### **Psychological stress moderating cortisol linkage**

Testing hypothesis 3 revealed that higher levels of psychological stress in women were associated with stronger cortisol linkage. This was not confirmed for men's psychological stress. These findings are broadly in line with findings from a study assessing similar processes during pregnancy (Braren et al., 2020). The authors found stronger cortisol linkage when maternal psychological stress was high, and no associations between paternal psychological stress and cortisol linkage. The authors argued that during pregnancy and after birth, mothers become more vigilant to environmental cues, presumably to protect their child (Braren et al., 2020). Mothers might therefore be more sensitive and more reactive to stressors at this particular time, and this may translate into heightened cortisol (Braren et al., 2020). Further insight into this possibility would require research linking parents' stress and coping responses to cortisol linkage. For example, men tend to use more denial or avoidance coping strategies than women (Baldwin et al., 2018), and their stress might affect the relational level less readily.

**Perceived partner responsiveness moderating cortisol linkage**

In contrast to our expectations, we found that perceived partner responsiveness was associated with weaker cortisol linkage. Specifically, at the assessment time level, perceived responsiveness of both partners was negatively associated with linkage, and at the daily level, cortisol linkage was lower when men reported high perceived responsiveness. Our expectation was based on the assumption that partners feel emotionally closer and are therefore more susceptible to a partner when they perceive the partner to be highly responsive. This could promote interpersonal regulation (Arican-Dinc & Gable, 2023) and at the physiological level, stronger cortisol linkage, given that stronger physiological linkage has been associated with closeness and connectedness (Chatel-Goldman et al., 2014; Papp et al., 2013; Timmons et al., 2023). Our data do not support this assumption.

Which processes could explain these unexpected results? The significant negative association between within-subject change in perceived partner responsiveness and dyadic cortisol linkage indicates that cortisol linkage between partners is weaker at assessment times at which partners perceive their partner to be more responsive, than at times when they see their partner as less responsive. This can reflect a pattern where perceived partner responsiveness decreases in a relationship and in parallel, cortisol linkage increases, which could be expected in the case of increased relational distress, based on prior findings (Liu et al., 2013). Insofar as diminished partner responsiveness characterizes distressed relationships, these results support the assumption that cortisol linkage is strengthened by relationship distress (Timmons et al., 2015). The potential of experiencing partner responsiveness to enhance self-regulation capacities could offer an alternative or complementary answer. Perceived partner responsiveness is an invaluable resource for individuals, enhancing their perceptions of control and reducing their reactivity to daily stressors (e.g., Alonso-Ferres et al.,

2020; Slatcher & Schoebi, 2017). Therefore, while fostering connection between individuals, it has the potential to facilitate affect regulation, reduce parents' vulnerability to stress, and to promote autonomy and independence (Feeney, 2007). If a within-subject association between perceived partner responsiveness and cortisol linkage can be replicated, then examining reactivity to daily stressors, self-regulation and autonomy as mediators could offer insight into the mechanisms underlying the current pattern of results.

Our findings on possible moderators of cortisol linkage could indicate that higher levels of stress may contribute to cortisol linkage between partners, while perceiving high partner responsiveness may reduce cortisol linkage. It is important to consider that in daily life, stress and partner responsiveness are not necessarily independent experiences but often go hand in hand. If stress and responsiveness counteract each other with respect to cortisol linkage, then it might be promising to examine interactions between the two in future work.

We operationalized cortisol linkage as concurrent daily covariation, which could stem from one partner's influence, mutual influence, or external factors affecting both partners. Refining analyses to consider in-phase linkage (which might point to increasing influence of one partner) and anti-phase linkage (which might suggest turn-taking dynamics) could provide further insight into interactional dynamics (Reed et al., 2013). Also, Timmons et al. (2015) underlined the importance of physiological linkage in specific contexts. This might mean that it could be more challenging to identify consistent patterns of associations between linkage and psychological or interpersonal processes during the transition to parenthood, given that it is a period in which such processes are particularly prone to change (Cowan & Cowan, 1995). In the current study, we measured cortisol linkage and associations at pregnancy, six months, and 18 months post-partum, which represent a wide time span to observe modifications in relationship processes and putative changes in cortisol linkage patterns. Partners are prone to

experiences heightened psychological stress (Saxbe et al., 2018) and may therefore be more sensitive to their partner's behaviors.

### **Strengths and limitations**

To our knowledge, this study is the first to assess cortisol linkage in a longitudinal design across transition to parenthood, using three different times of assessment up to 18 months after birth. Expecting the first child involves many changes for partners at the social, psychological, and physiological levels. The longitudinal design we used allowed to frame a broader picture of the potential biological changes in couples and their cortisol linkage and the interpersonal processes occurring between partners over this time. Moreover, we assessed couples across three consecutive days at each time point, which allowed us to capture the variability in cortisol changes between partners as well as to model diurnal cortisol rhythms and linkage between partners.

Nevertheless, important limitations of this study must be taken into consideration when interpreting the results. First, we operationalized cortisol linkage as a concurrent covariation of cortisol levels. The use of a cross-lagged analyses over short time spans could help identifying specific directionality of the linkage processes. Additionally, assessing linkage across several days may contribute to a greater understanding of daily dynamics between partners. However, it may be more intricate to find associations with specific relational processes. Instead, focusing on linkage between narrower time points (e.g., social support or conflict interactions) may allow a better identification of relational mechanisms, through physiological recovery, for example (Powers et al., 2006). Alternatively, focusing on in-phase and anti-phase linkage could also bring another perspective on the topic of physiological linkage and relationship processes (Reed et al., 2013). Moreover, because saliva samples were self-collected, we had limited control over the sampling time and adherence to the protocol. To increase the control over

saliva sampling time was controlled by MEMS caps. Specifically, we expected that new parents may have had more difficulties to strictly follow the protocol with a newborn. Generalizability is also limited as couples of the current study showed higher than average income and education and were relatively highly satisfied with their relationships. Combining financial strain with the arrival of an infant may considerably heighten the distress of couples in their daily life and may be measured at the physiological level too and therefore potentially result in other findings. Additionally, it is important to consider that women's hormonal regulation of glucocorticoid steroid hormone is dependent on the preparation to the birth, which may affect cortisol secretion, and thus may not provide a precise picture of the role of physiological linkage in relationships. When controlling for weeks of pregnancy, we found that pregnancy stages were significantly and positively predicting cortisol.

### **Conclusion**

The present study sheds light on cortisol linkage between partners in a challenging, yet normative period for couples. Although cortisol linkage has been defined as a regulatory and mutual process, in which partners aim to maintain a relatively stable system (Butler, 2011), it remains unclear how relationships may be a regulator of physiological activity. The current results provide further evidence for cortisol associations between partners and highlight how cortisol linkage changes from pregnancy to six months, and from six to 18 months post birth. The challenges and stress new parents experience in their daily life appear to shape the emotional and physiological dynamics of the couple. Our findings also provide further evidence on the moderation effects of relational and psychological processes. In line with previous studies, psychological stress was associated with stronger linkage. Moreover, perceived partner responsiveness did not contribute to strengthening cortisol linkage but instead was negatively associated with linkage. These findings point to the possibility that in a

particularly sensitive period of transformation in the partnership, cortisol linkage is susceptible to vary as a function of self-regulatory and interpersonal processes.

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