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# Relation of Intimate Partner Violence to Salivary Cortisol among Couples Expecting a First Child

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## Abstract

Despite advances in understanding the role that several physiological systems play in the occurrence of general violence, little progress has been made toward understanding biological correlates of Intimate Partner Violence (IPV). We explored involvement of one physiological system, the hypothalamic-pituitary-adrenal (HPA) axis. Among 137 heterosexual couples expecting a first child, baseline level of HPA activity -- assessed via salivary cortisol collected before a couple conflict discussion -- was linked to both men's and women's violence perpetration. HPA reactivity to the conflict bout did not show an independent association with IPV. However, persisting elevation in men's, and down-regulation in women's, HPA activity during a further recovery period was linked to men's violence perpetration.

## Relation of Intimate Partner Violence to Salivary Cortisol

Violence among married and unmarried couples carries a heavy public health burden (Krug, 2002). Relationship violence is linked to psychological disorder, injury, and death, as well as to disrupted parenting and child mental and behavioral health problems (El-Sheikh et al., 2008; Grych & Fincham, 2001; Levendosky et al., 2006; Tolan, Gorman-Smith, & Henry, 2006). Recent data indicates this problem is much more prevalent than previously understood. Physical aggression between partners occurs in half of all families with young children each year, according to an anonymous, representative study (Slep & O'Leary, 2005). Among these families, physical aggression does not only consist of relatively mild forms such as pushing and shoving—half of these families report high severity violence. And contrary to common stereotypes, the majority of violence does not consist of male-to-female aggression: Violence is reciprocal in most families reporting any aggression, with the remaining families demonstrating an approximately even split between male-to-female and female-to-male violence (Capaldi, Kim, & Shortt, 2007; Straus, 1990; Straus, Gelles, & Steinmetz, 1980).

Given the prevalence and burden of couple violence, it is surprising that there has been almost no research seeking to understand the psychobiological correlates and concomitants

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of interpartner violence (IPV; but see (Hibel et al., 2009)). Moreover, some of the best known work—that of Gottman and colleagues linking heart rate reactivity to a marital conflict discussion to observed verbal aggressiveness during that discussion among “batterers” (Gottman, Jacobson, Rushe, & Shortt, 1995; Jacobson et al., 1994)—was conducted on a small sample and independent replications failed to support the original findings (Babcock, Green, Webb, & Graham, 2004; Meehan, Holtzworth-Munroe, & Herron, 2001). Some other work has included IPV as a dimension of investigation, but did not report on links between physiology and IPV *per se*: For example, one study found that physiological reactivity (heart rate, skin conductance) to couple conflict predicted antisocial behavior differently across couples stratified by level of violence (Babcock, Green, Webb, & Yetington, 2005).

This gap in the literature on couple violence is notable given the mounting number of studies examining biological processes underlying antisocial and violent behavior outside of such relationships (Raine, 2002). In this paper, we argue that--based on existing knowledge about the role of physiological systems in aggression--it is reasonable to expect that couple violence is linked to physiological arousal generally and to the activity of the hypothalamic-pituitary-adrenal (HPA) axis in particular.

The HPA axis is one of two main physiological components of the psychobiological of the stress response (Chrousos & Gold, 1992). The HPA is activated in a systemic response to social evaluative threat or challenge (Dickerson & Kemeny, 2004). Cortisol is the primary product released from the adrenals in response to HPA axis activation and its levels in the general circulation can be estimated accurately and non-invasively in saliva. In general, adaptive functioning is linked to moderate increases in cortisol in reaction to a stressor or challenge, followed by recovery to baseline (Dickerson & Kemeny, 2004). Several studies have documented links between HPA activity, indexed by cortisol levels in blood or saliva, and aggressive or socially disruptive behavior (Granger et al., 1998a; Oosterlaan, Geurts, Knol, & Sergeant, 2005). For example, Granger and colleagues found that children’s pre-task cortisol levels were negatively associated with the open expression of aggression in the family (Granger et al., 1998a).

We hypothesized that IPV is associated with increased HPA reactivity and delayed HPA recovery to interpersonal conflict. Perpetrators of IPV experience greater emotional arousal and anger (by both self-report and observation) during conflict tasks with a partner compared to non-violent individuals (Margolin, 1988; O'Leary & Jouriles, 1994). A meta-analysis found that male perpetrators of IPV experience higher levels of anger than non-perpetrators in conflictual relationships (Norlander, 2005), and that among perpetrators of IPV, anger is associated with greater severity of violence. Anger and emotional arousal are often accompanied by increased cardiovascular activity and/or activation of the HPA axis (Abercrombie, Kalin, & Davidson, 2005). HPA axis activation provides the individual with a physiological state of readiness to respond rapidly and energetically to an anger-provoking stimulus, thus facilitating aggressive responses. In addition, cortisol elevation affects cognitive processing in a manner that may increase the likelihood of selecting an aggressive response. For example, in the course of priming the body for action, HPA axis activation affects brain physiological functioning, executive functioning, and access to emotional memories (Abercrombie et al., 2003; Cahill, Gorski, & Le, 2003). Such effects may reduce the ability to engage in adaptive problem solving and increase the likelihood of primitive behavioral responses such as aggression.

Further circumstantial support for the hypothesis that IPV is associated with HPA activity is provided by the documented associations of both to hostile, conflictual couple interaction. Several studies report dyadic conflict to be associated with increases in cortisol (Granger et al., 1998b; Kiecolt-Glaser, Bane, Glaser, & Malarkey, 2003; Robles, Shaffer, Malarkey, & Kiecolt-Glaser, 2006), an association that is moderated by individual coping and romantic attachment styles (Gunlicks-Stoessel & Powers, 2009; Powers, Pietromonaco, Gunlicks, & Sayer, 2006). Negative couple interaction, marked by low warmth, high hostility, and verbal and psychological aggression, is also linked to perpetration of IPV (Cano & Vivian, 2003; Riggs & O'Leary, 1996; Riggs, O'Leary, & Breslin, 1990). However, IPV and HPA activity have not yet been linked directly.

Based on the findings for HPA reactivity and couple conflict, we would expect high levels of HPA activity to be positively associated with IPV. However, there is also reason to expect that low HPA activity levels would predict greater IPV. Research on general aggression and violence frequently finds that aggressive and/or violent children, adolescents, and adults demonstrate relatively low levels of physiological activity or reactivity (Loney et al., 2006; Oosterlaan et al., 2005; Raine et al., 2000). A leading theory is that hypo-responsive individuals do not react strongly to negative consequences of behavior—such as being hit back by a peer or punished by a parent. Thus, the normal mechanisms through which impulses to physical aggression are socialized into more adaptive behavior do not occur, resulting in “under-socialized aggression”. One goal of this study was to assess whether HPA reactivity would relate to IPV in the same direction as it does to couple conflict (a positive association) or as it does to general violence (i.e, a negative association).

Most prior physiological research on couple conflict has been framed in terms of reactivity —that is, comparing a change in cortisol following conflict to a pre-conflict baseline. However, adaptive functioning is characterized by both reaction to a stimulus and then recovery toward baseline. Indeed, the recovery process from a stressful episode may be as important for individual well-being as the reaction (Burke, Davis, Otte, & Mohr, 2005). Physiological recovery may also play an important role for couple relationship dynamics (Frankenhaeuser, 1986; Powers et al., 2006). Individual capacity for recovery may contribute to the successful repair of dyadic conflict episodes, which facilitates positive relationship quality over time (Dindia & Baxter, 1987). Repair of negative interaction episodes includes acknowledging and/or apologizing for an insult, re-establishing a mutual sense of respect or affection, and/or returning to a positive affective state. Individual recovery may set a lower limit on capacity for repair.

The temporal pattern of the psychobiology of the stress response allows for a simple assessment of reactivity and recovery. HPA axis response to an acute stressor, as assessed in salivary cortisol, generally peaks after approximately 20 minutes, and recovery toward baseline develops over the subsequent 20–40 minutes (Dickerson & Kemeny, 2004). Although a spike in hostile conflict during an argument may pass without violence, individuals who have difficulty down-regulating physiological arousal may be primed to react aggressively when a second (or third, etc) conflict stimulus occurs before levels of cortisol have returned to baseline.

Finally, in addition to reactivity and recovery, we examine the possibility that baseline level of cortisol is related to IPV. If, as we note above, HPA axis activation facilitates rapid reaction to adverse or threatening stimuli, then the existing level of HPA activity marked by cortisol level may influence the way an individual responds to an ambiguous or hostile social situation.

In this report, our aim is to test the link between HPA activity and IPV as a prelude to future work that should attempt to more precisely understand context, process, and temporal influence (e.g., moderators, mediators, and causality). We focused this investigation on the transition to parenthood because this developmental period is often marked by heightened stress and brings new challenges to couple relationships (Cowan, 1995; Feinberg, 2002). Cumulative stressors during this time may increase the likelihood of violence, which poses physical risk to the mother and developing fetus (Jasinski, 2004). Additionally, both prenatal and postnatal violence and hostility can have negative implications for parenting and child development (Katz & Low, 2004).

To assess HPA activity, we collected data from the couples in their home. We collected baseline saliva samples from each member of a couple before two 12-minute videotaped interactions, the second of which was a conflict discussion. We then collected a second saliva sample 15 minutes after the end of the interaction period to measure reactivity, and a third 20 minutes later to measure recovery. We then utilized this data to predict several dimensions of couple violence obtained through self-report measures.

We examined the prediction of low and high severity violence separately based on the notion that different processes may be involved. For example, high-severity violence might be the result of relatively more intense anger or a greater loss of conscious inhibitory control. Research supports the notion that perpetrators of low- and high-severity violence may be comprised of two or more somewhat distinct groups (Holtzworth-Munroe & Meehan, 2004). Although sample limitations did not allow us to examine subtypes of violence perpetrators, assessing separately the prediction of low and high severity may provide some information relevant to subgroup issues. We also examined violence resulting in injury as a separate outcome, as causing injury to a partner could result from “low severity” violence behaviors (e.g., slapping or pushing) enacted during extreme experiences of anger or physiological arousal. Finally, we examined prediction of psychological aggression, which consists of behaviors such as insulting or shouting. Psychological aggression has negative effects on victims, and commonly occurs alongside physical aggression among couples (Capaldi, Shortt, & Crosby, 2003).

## Methods

Participants were both members of 137 heterosexual couples that were expecting their first child and participating in a randomized study testing a psychosocial prevention program for first-time parents. The full study included 169 couples; however, we only attempted to collect cortisol with 137 for budgetary reasons. These couples provide data for the analyses presented below. Only pretest data are included in the present study; therefore, the intervention will not be discussed further. Couples were primarily recruited from childbirth education programs at two hospitals located in small cities with nearby rural areas. Eligible couples were living together, were over 18 years old, and were expecting their first child.

Participating couples resided in rural areas, towns, and small cities. Eighty-one percent of couples were married (compared to 67% of parents of all infants born in the U.S.) and the majority of participants (91% of women and 90% of men) were Non-Hispanic White. The remaining participants were Non-Hispanic Black, Non-Hispanic Asian, Hispanic, or other races. Median annual family income was $65,000 ranging from $2,500 to $162,500. Average educational attainment was 15.0 years for women (*SD* = 1.8) and 14.4 years for men (*SD* = 2.2); 84.8% of women and 68.9% of men had at least some post-secondary school education. Mean ages were 28.3 (*SD* = 4.9) years for women and 29.7 (*SD* = 5.6) years for men. At the time of data collection, the number of weeks gestation ranged from 9 to 36 weeks (mean=22.4; *SD*=5.3).

### Procedure

Our university’s IRB approved all procedures, and respondents read and signed approved informed consent forms. Data were collected during a home visit by a trained research assistant. Because of the typical declining circadian rhythm of cortisol, we attempted to interview couples in the afternoon or evening: 83% of couples were interviewed after 2 pm, 73% after 4 pm (start time of interviews ranged from 10:30am to 8:30pm). Expectant mothers and fathers separately completed questionnaires regarding their relationship experiences, individual qualities and attitudes, and individual well-being. In order to assess family relationships apart from the potential bias of self-report, interviewers collected two 12-minute videotaped interactions of each couple before administering the questionnaire packets. For the first task, couples were asked to talk about their day or about something that was on their mind but not related to their relationship. Each partner took turns spending six minutes as the primary speaker and six minutes as the listener. For the second task, couples were asked to talk about three problems in their relationship; the three problem areas for each couple were selected by the interviewer based on which items each partner had rated highly on a list of potential desired changes.

**Saliva sampling—**During the course of the home interview, three salivary samples were obtained from participants and later assayed for cortisol. A baseline sample ($t_0$) was collected at the beginning of the home visit, shortly after the interviewer explained the procedures and obtained consent. The 2$^{nd}$ sample ($t_1$, reaction) was collected 15 minutes after the end of the conflict discussion (which was, on average, about 49 minutes after the baseline sample). The 3$^{rd}$ sample ($t_2$, recovery) was collected 20 minutes after the 2$^{nd}$ sample. Cortisol levels are affected by recent meals (Gibson et al., 1999). Subjects were asked not to eat for one hour prior to the home visit; if the subject had reported eating during that period, the cortisol-related tasks were conducted at the end of the home visit to satisfy that requirement. Interviewer notes were consulted to ensure participant compliance, health status at the interview (i.e., not ill), and other factors.

**Cortisol Determination—**After collection, saliva samples were kept on ice, frozen within eight hours, and stored at − 20 C until transported to Salimetrics laboratories (State College, PA) were they were stored at −70 C until the day of assay. On the day of testing, samples were thawed and then centrifuged at 3000 rpm for 15 minutes to remove mucins. Samples were assayed using a commercially available enzyme immunoassay for salivary cortisol without modification to the manufacturers recommended protocol (Salimetrics LLC). The test used 25 ul of saliva, had a lower limit of sensitivity of .007 ug/dL, range of sensitivity from .007 to 3.0 ug/dL, and average intra-and inter-assay coefficients of variation of less than 5% and 10%. All samples were tested in duplicate, and the average of the duplicate tests was used in the analyses. Cortisol units are expressed in micrograms per deciliter (ug/dL).

**Violence—**To measure physical and psychological aggression in the couple relationship, we used the physical assault, psychological aggression, and physical injury subscales of the Revised Conflict Tactics Scales (Straus, Hamby, Boney-McCoy, & Sugarman, 1996). For physical assault, expectant mothers and fathers completed eight items about their own behaviors perpetrated toward their partner and the same eight items about their partner's behavior toward themselves. Three of these eight items are distinguished as "low-severity" (e.g., threw something at partner), while five are distinguished as "high-severity" (e.g., utilizing a weapon, choking). With the same format, respondents reported on four items for psychological aggression and four items for physical injury. Physical injury items assessed consequences of an aggressive event (e.g., "My partner went to a doctor because of a fight with me"). All items had a 7-point scale ranging from *0 times* to *More than 20 times* in the past year, with the additional option of *Not in the past year, but it did happen before*. Past year frequency of violence was calculated by recoding each item score as the midpoint of the response category (e.g., 3 to 5 times per year was recoded as 4) and summing across items. Given the possibility of underreporting of violence and injury, we considered data from both expectant mothers' and fathers' reports to determine each respondent's violence outcome using a method consistent with previous research (e.g., (Gordis, Margolin, & Vickerman, 2005; Slep & O'Leary, 2005)). Specifically, we used the highest frequency reported by either parent as the frequency for that behavior. (Internal consistency could not be calculated because there were several items for which all parents indicated that the behavior did not happen in the past year, and there was no variance in these items as a result. Straus and colleagues' original psychometric assessment of the scale indicated high levels of internal consistency: physical assault=.86; psychological aggression=.79; injury=.95).

For statistical models, two of the four outcomes -- injury perpetration and high-severity physical assault -- were converted to dichotomous outcomes (0=none; 1=presence). We re-scaled these outcomes because roughly 90% of expectant parents indicated that no such violence had occurred. Low-severity physical assault and psychological aggression counts were left in the original frequency scale, although extreme cases were truncated (at a count of 30 and 65 for the two outcomes, respectively) in order to reduce the influence of outliers on analytic models (affecting five extreme cases for physical assault and three extreme cases for psychological aggression).

## Results

### Preliminary analyses

**Salivary Cortisol—**The means (standard deviations) of the three cortisol assays were, for mothers: $t_0$ = .161 ug/dL (.109), $t_1$ = .132 ug/dL (.079), $t_2$ = .126 ug/dL (.079); and for fathers were $t_0$ = .095 ug/dL (.067), $t_1$ =.074 ug/dL (.053), $t_2$ = .066 ug/dL (.049). Baseline cortisol levels were negatively related to the time of day for expectant mothers, $r = -.58$, $p < .001$, and fathers, $r = -.56$, $p < .001$, in accordance with the general decline of HPA activity in healthy individuals over the course of a day. Consistent with this downward trend in HPA axis activity, the mean cortisol values for the three samples demonstrated a negative slope, declining from $t_0$ to $t_2$. Despite this overall trend, increased cortisol from baseline ($t_0$) to the expected reactivity time point ($t_1$) was found in 15.3 percent of the women and 19.0 percent of the men. Given that the expected elevation in cortisol level as a result of the couple discussion was countered by the diurnal pattern (see Discussion), high or low reactivity/recovery is referred to in the rest of this paper as relative to mean reactivity/recovery and not to absolute change in cortisol.

Baseline cortisol levels were negatively associated with cortisol reactivity (expectant mothers, $r = -.76$, $p < .001$; fathers, $r = -.62$, $p < .001$) and demonstrated a moderate positive correlation with recovery (expectant mothers: $r = .35$, $p < .001$; fathers: $r = .34$, $p = .001$). However, reactivity was not significantly correlated with recovery ($r = -.15$, $p = .08$ and $r = .06$, n.s., for expectant mothers and fathers, respectively). Expectant mothers' and fathers' baseline cortisol levels were moderately associated ($r = .38$, $p < .01$), but within-dyad associations were not significant for reactivity ($r = .14$, n.s.) or recovery ($r = -.15$, n.s.). Number of weeks gestation was modestly associated ($r = .17$, $p < .05$) with expectant mothers' baseline cortisol. Use of anti-inflammatory steriod medications (four men and five women) was associated with lower levels of expectant fathers' baseline cortisol at a trend level ($p < .10$).

Because of a moderate positive skew, baseline cortisol levels for regression models were adjusted using a Box-Cox transformation. The measure of reactivity ($t_1 - t_0$) and recovery ($t_1 - t_2$) were computed using the untransformed values, and these difference scores had approximately normal distributions. Positive reactivity values represent an increase in cortisol level from $t_0$ to $t_1$, and positive recovery values represent a decrease in cortisol from

$t_1$ to $t_2$. Finally, given the influence of time-of-day and (for females) number of weeks gestation on cortisol levels, we used regression models to remove the impact of those measurement artifacts for each participant's cortisol values. All results presented below are based on these "residualized" cortisol values.

**Violence—**According to the highest reported level of violence perpetration, 33.1% of mothers and 20.1% of fathers had ever engaged in at least one low-severity violent act, and 12.4% of mothers and 10.1% of fathers had ever engaged in at least one high-severity violent act. Of these parents, the average number of violent acts perpetrated in the last year was 8.2 low-severity acts and 5.6 high severity acts by mothers, and 8.0 low severity and 2.2 high severity acts by men. In the full sample, mothers perpetrated 2.4 low severity acts and 0.9 high severity acts and fathers perpetrated 1.4 low severity acts and 0.2 high severity acts on average in the past year.

## Predicting Violence

**Baseline cortisol—**We conducted multilevel regression models (parents nested within couple) to examine the relationship between cortisol values and violence. Models included a random intercept to represent variation at the family-level. As in the Actor-Partner Interaction Model (Cook & Kenny, 2005), we included the individual's own cortisol value(s) as well as the partner's value(s) as predictors. To test whether associations differed across partners, separate interaction terms representing gender (0=male, 1=female) with own and partner cortisol values were tested in all models. Non-significant interaction terms were dropped. We utilized a step-wise procedure to examine baseline cortisol as a predictor in Step 1, reactivity while controlling for baseline values in Step 2, and recovery while controlling for baseline and reactivity values in Step 3. To appropriately analyze the highly dispersed count outcomes (frequencies of low-severity physical assault and psychological violence) we used a negative binomial regression model. Logistic regression was used for the dichotomous high-severity physical assault and injury outcomes.

Table 1 provides the results from the regression models. Not shown in Table 1 is the coefficient representing parent (gender) association with violence regardless of cortisol level. Results for this gender main effect were consistent across models: significant differences between parents were found in models predicting low-severity physical assault ($b$=.66 in baseline cortisol model; $p<.001$ for all cortisol models), indicating that women were more likely to aggress than men. There were no statistical differences between males and females for perpetration of high-severity violence, psychological aggression, or injury.

Results indicate that for both men and women, the individual's own baseline level of cortisol significantly and positively predicted injury perpetration and both low and high severity physical assault ($p<.05$). The association between baseline cortisol and psychological aggression was positive but not as strong ($p=.059$). Partner's baseline cortisol was significantly, positively associated with being the victim of high-severity physical assault ($p<.05$), but not with the other outcome variables. There were no significant interactions between baseline cortisol and gender, and these terms were dropped.

**Cortisol Reactivity—**There are both substantive and methodological reasons for expecting baseline cortisol and reactivity to be non-independent, and indeed the correlation between baseline and reactivity was moderate and significant (expectant mothers, $r = -.36$, $p < .001$; expectant fathers, $r = -.39$, $p < .001$). There is no generally accepted approach to handle this matter at present. Controlling for baseline level in the model represents a test of whether reaction accounts for violence above and beyond baseline levels. In such models including baseline level (Step 2 in Table 1), there were no significant associations of either the individual's own or the partner's cortisol reactivity with violence for any of the three outcomes.

We also assessed the possibility that low reactivity (as found in research on antisocial and aggressive individuals) and high reactivity (as found in research on couple conflict) are both linked to IPV. To test this possibility, we examined whether the absolute value of reactivity, which was centered at zero, would predict the three outcomes. Results of this assessment (not tabled) indicated no significant association between absolute value of the reactivity score and any of the violence outcomes.

**Cortisol Recovery—**Results from the models examining cortisol recovery are more complex. A significant gender interaction was found for cortisol recovery predicting psychological aggression and injury perpetration (both $p<.05$). For expectant fathers, cortisol recovery was negatively linked to both their psychological aggression and injury perpetration, indicating that individuals with higher recovery rates were less likely to be violent with their partner in these manners. In conducting the analysis with the gender dummy code reversed, expectant mothers' recovery was not significantly associated with psychological aggression and injury perpetration. The same general pattern was found for expectant fathers' and mothers' recovery predicting low and high severity violence, but results for these outcomes were not significant.

The influence of partner recovery on violence demonstrated a contrasting pattern of findings between genders for the low and high severity physical assault outcomes and injury perpetration; that is, significant gender interactions were found for each of those outcomes. In each case, higher recovery in expectant mothers was associated with higher rates of violence committed against them by their partner ($p<.05$ for low-severity physical assault and injury; $p=.075$ for high-severity physical assault). We found that higher recovery in expectant fathers was associated with less violence perpetrated by their partner, but in no case were these associations significant (assessed by reversing the gender dummy code).

For psychological aggression, the effect of partner (women's) recovery was non-significant for men, whereas a significant gender interaction indicated that lower partner (men's) recovery predicted higher psychological aggression by women (a model with the dummy coding reversed found this association to be significant at $p<.05$).

## Discussion

The results of this study indicate that reports of intimate partner violence (IPV) in the past year—including physical violence, psychological violence, and injury perpetration—are linked to levels of the activity of the HPA axis obtained both before and after a couple conflict discussion task. Moreover, within expectant heterosexual couples, divergence in cortisol recovery appears to be linked to violence. These findings are the clearest indication to date that couple violence is linked to components of the psychobiology of the stress response—here, HPA axis activity—and that consideration of the joint pattern of these fluctuations across partners may play an important role. Moreover, the pattern of findings is different than has been found previously for general physical aggression.

Baseline cortisol levels, but not cortisol reactivity assessed as the change from baseline to a point after the couple conflict discussion, was directly and positively related to aggression. This finding is consistent with a view that elevated levels of HPA axis activity facilitate the selection of aggressive responses and/or the enactment of aggressive strategies. Such effects may take place through both emotional pathways, such as the increase of anger, and through cognitive pathways as outlined in social information processing theories (Roelofs et al., 2007). The lack of a link between cortisol reactivity to couple conflict discussion and aggression was surprising, but may be due to the non-independence of baseline and reactivity measures. There are both substantive and methodological reasons for expecting baseline cortisol and reactivity (change from baseline) to be non-independent, and indeed these measures were correlated. There is no standard approach that is generally accepted to handle this matter at present in HPA axis research, and many prior investigations have ignored this issue when examining the link between physiological reactivity and behavior. We employed the conservative approach of controlling for baseline when examining HPA reactivity. Given these issues, we feel the distinctive role of HPA baseline activity and reactivity deserves further examination in other study designs and with other samples—especially with large enough samples in order to conduct more sophisticated analyses. Indeed, all the results in this study require replication and further examination in other samples and study designs.

It is notable that elevated pre-task cortisol was linked to greater IPV, whereas most research has found that physiological “under-arousal” of heart rate and electro-dermal activity at baseline characterizes violent or aggressive individuals (Lorber, 2004). We point out that not only are different physiological systems being compared here, but the context of an intimate partner relationship is quite different than the context of most general violence. Moreover, previous research indicates that male perpetrators of IPV only are different in certain respects from the smaller group (about 10% of all IPV perpetrators) of IPV perpetrators who also demonstrate violence in other contexts (Delsol, Margolin, & John, 2003). We suspect that the participants in this sample represent primarily IPV-only individuals, as generally violent individuals may have been less likely to volunteer in a community-based study (Kan & Feinberg, 2007). A reasonable hypothesis is that the smaller, generally violent group of IPV perpetrators may demonstrate a pattern of under-arousal, whereas the romantic relationship-specific violence perpetrators demonstrate the pattern of elevated HPA axis activity detected in this study. Thus, future research should examine whether these two empirically distinct types of IPV perpetrators also demonstrate differences in physiological functioning.

The most complex and intriguing pattern of results to emerge from the study was for the prediction of violence by cortisol recovery. We found that a low level of cortisol recovery for men was linked to both psychological aggression and perpetration of injury. This finding is extremely important given the potential of men’s violence to cause serious injury and death to women and unborn children. One reason cortisol recovery may play an important role in the emergence of couple violence relates to the fact that conflict bouts in real-life situations are not neatly condensed into 10 or 12-minute segments as in research studies. For example, a spike in hostile conflict during an argument may pass quickly; however, hostility may reappear 15 or 30 minutes later as the same issue--or a new issue--triggers further conflict. Men who have difficulty with physiological recovery, and therefore continue to have elevated levels of circulating cortisol, may be primed to “over-react” to repeated or episodic conflict bursts. However, we know little about the causal mechanism linking low cortisol recovery (i.e., persisting elevated levels of cortisol) and violence. For example, difficulty down-regulating physiological arousal may facilitate heightened levels of negative emotion and undermine complex cognitive processing. On the other hand, psychological mechanisms such as a globalizing attribution style or persisting rumination may trigger or sustain emotional reactions that impede down-regulation of HPA system activation (Byrd-Craven, Granger, & Auer, In press). We expect future research will illuminate reciprocal relations between HPA activity and psychological-behavioral mechanisms involved in IPV.

There was no such link between women’s cortisol recovery and their violence perpetration. Instead, women’s cortisol recovery was inversely linked to men’s violence and injury perpetration: When a woman demonstrated more recovery, her partner was more likely to have perpetrated violence and caused injury in the past year. We cautiously interpret these results based on the notion that down-regulation of HPA activity may be related to emotional disengagement from a conflict. Marital therapists often point to the way that conflict can serve to bind individuals together in a relationship. Thus, a woman's disengagement or withdrawal from the conflict, while the man continues to experience emotional arousal and stress, may lead some men to experience a sense of abandonment or loss of control (Babcock, Jacobson, Gottman, & Yerington, 2000; Dutton & Browning, 1988; Lafontaine & Lussier, 2005). In fact, high levels of dependency and insecure attachment have been linked to IPV (Allison, Bartholomew, Mayseless, & Dutton, 2008; Babcock et al., 2000; Mauricio & Gormley, 2001). Thus, it may be possible that greater cortisol recovery in a woman is associated with greater disengagement from the conflict—and this disengagement is experienced as abandonment and loss of control among some men, who then resort to violence as a maladaptive means of reasserting an emotional bond or control.

As most IPV occurs in the context of mutual conflict and aggression (Johnson, 1995), male aggressive reactions would be expected to lead to reciprocated violence perpetration by women. Thus, one might expect that if greater recovery among women leads to more male violence, then these women would tend to reciprocate, thus perpetrating more violence as well. This indirect pathway would counteract the expected direct effect of women's recovery on lowering the likelihood of a woman's violence perpetration. Indeed, our findings that women's cortisol recovery was linked to greater violence perpetration, but that these associations were weak and non-significant, is consistent with the expected *combined* effect of both the direct and indirect (via partner behavior) effect of women's recovery on violence perpetration. This hypothesis suggests that the time course of the activation and recovery of physiological systems in both partners may be important to understand as part of a complex dyadic and dynamic biobehavioral system.

Although this *post-hoc* account has some appeal and is consistent with the literature on IPV, it also may be that gender differences in how men and women respond to threat play a role. For example, in addition to the HPA-axis driven "flight or fight" response, an oxtyocin-mediated "tend and befriend" response to threat may characterize women's response (Taylor et al., 2000). This area of inquiry is rich with possibilities for speculation, theory-building, and empirical investigation.

## Limitations and Future Research

Further research is also needed to understand whether the results of this study hold for most couples, or whether the links between HPA activity and violence are moderated by individual and couple level factors. Baseline level of cortisol, depression, economic strain, couple relationship satisfaction, and a number of other factors may define the dimensions along which the links between HPA functioning and violence vary. For example, men's personality and both partners' stress levels have been shown to predict trajectories of physical aggression (Langer, Lawrence, & Barry, 2008). The attachment security of partners and qualities of the couple relationship may represent other important factors for future theory and research to explore. Moreover, incorporating information about the topic of conflict and which partner who raised the issue may provide further understanding of the meaning of HPA functioning in studies of reactivity.

Moreover, we point out that replication using other study designs is needed; it is possible, for example, that the link between baseline cortisol and aggression may have been due to the home visit procedures. That is, "baseline" cortisol may have been influenced by reaction to the start of the home visit procedures: Individuals who experienced a greater level of stress due to the presence of the home visitor may also be more likely to injure their partner. The current design is unable to distinguish between these alternative interpretations.

In addition to the HPA axis, other physiological systems are likely related to couple relationship quality and/or aggression. For example, testosterone levels in men appear to decrease during partner's pregnancy, which may have affected actual levels of aggression as well as perhaps perceptions of past aggression (Berg & Wynne-Edwards, 2001). And oxytocin may be related to attachment aspects of close relationships as well as to cortisol levels (Neumann, 2008). Future research should investigate a wider range of physiological systems and markers.

Our investigation was motivated by the general hypothesis that HPA activity influences violent behavior. However, it is clearly possible that HPA activity influences levels of arguing and general tension and conflict in the relationship, which then leads to violence. Moreover, the causal direction may be reversed: A history of violence within a couple may influence fluctuations in HPA activity. Existing evidence suggests that social experience can influence children's HPA activity patterns (Blair et al., 2008; Granger et al., 1996). Future research should explore similar possibilities with adults; for example, a history of relationship violence may lead individuals to become hypervigilant and physiologically aroused when in the presence of the partner. Because of its sporadic but intense nature, IPV history may stimulate habituation-resistant physiological arousal. In a hyper-aroused state, individuals may be more likely to interpret ambiguous social cues as hostile (Lansford et al., 2006), and thus may more quickly take defensive, hostile action. Hypotheses regarding such self-reinforcing social-psychological relationship patterns have been put forth previously; here, we speculate that there may be a physiological component to this process. Our findings would be consistent with not only elevated baseline HPA levels as a result of IPV, but also alteration in women's recovery processes from a conflict bout. That is, it may be that women who have been injured by their partner in the past have learned to quickly down-regulate levels of arousal in order to minimize the potential for conflict to escalate to violence.

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## Table 1

Results from multilevel negative binomial regression models predicting violence outcomes

| | Physical assault high-severity | | | | Physical assault low-severity | | | | Physical assault high-severity | | | | Injury | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Predictors** | **B** | **SE** | **z** | **P>\|z\|** | **B** | **SE** | **z** | **P>\|z\|** | **B** | **SE** | **z** | **P>\|z\|** | **B** | **SE** | **z** | **P>\|z\|** |
| Step 1: Baseline | | | | | | | | | | | | | | | | |
| Own baseline cortisol | *2.78* | *1.47* | *1.89* | *0.059* | **0.66** | **0.30** | **2.15** | **0.032** | **1.62** | **0.65** | **2.49** | **0.013** | **2.66** | **8.76** | **2.36** | **0.018** |
| Partner baseline cortisol | 1.65 | 1.56 | 1.06 | 0.291 | 0.24 | 0.33 | 0.73 | 0.464 | **1.29** | **0.63** | **2.07** | **0.039** | 8.57 | 8.12 | 1.06 | 0.291 |
| Step 2: Reactivity | | | | | | | | | | | | | | | | |
| Own reactivity | 0.09 | 2.48 | 0.04 | 0.972 | 6.07 | 6.10 | 1.00 | 0.319 | −2.73 | 9.18 | −0.30 | 0.766 | −9.50 | 13.80 | −0.69 | 0.491 |
| Partner reactivity | 0.62 | 2.61 | 0.24 | 0.813 | 1.84 | 6.69 | 0.28 | 0.783 | 1.41 | 8.45 | 0.17 | 0.868 | 8.32 | 11.27 | 0.74 | 0.461 |
| Step 3: Recovery | | | | | | | | | | | | | | | | |
| Own recovery | **−10.41** | **5.29** | **1.97** | **0.049** | −4.66 | 12.70 | −0.37 | 0.714 | −34.22 | 25.70 | −1.33 | 0.183 | **−58.58** | **28.09** | **−2.09** | **0.037** |
| Partner recovery | 5.47 | 5.16 | 1.06 | 0.289 | **35.37** | **17.81** | **1.99** | **0.047** | *44.94* | *25.22* | *1.78* | *0.075* | **60.67** | **28.34** | **2.14** | **0.032** |
| Own recovery × Gender | **13.48** | **6.71** | **2.01** | **0.045** | 21.60 | 16.17 | 1.34 | 0.182 | 50.67 | 32.62 | 1.55 | 0.120 | **88.32** | **40.34** | **2.19** | **0.029** |
| Partner recovery × Gender | **−15.23** | **6.85** | **2.22** | **0.026** | **−53.65** | **19.98** | **−2.68** | **0.007** | **−74.48** | **33.88** | **−2.20** | **0.028** | **−90.14** | **39.15** | **−2.30** | **0.021** |

*Note*: Step 2 includes control for baseline cortisol values, and Step 3 includes control for baseline and reactivity cortisol values. Bold-face indicates significance at p<.05, italics indicates significance at p<.10. Own cortisol refers to the perpetrating individual’s own cortisol baseline, reactivity, or recovery score. Gender: 0=male, 1=female.