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Journal
Journal of Behavioral Medicine, 41(5)

ISSN
0160-7715

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Publication Date
2018-10-01

DOI
10.1007/s10865-018-9947-2

Peer reviewed

J Behav Med (2018) 41:722–732
https://doi.org/10.1007/s10865-018-9947-2

Partner relationship satisfaction, partner conflict, and maternal cardio-metabolic health in the year following the birth of a child

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Received: February 26, 2018 / Accepted: June 26, 2018 / Published online: July 7, 2018

Abstract Intimate partner relationship quality during the child-bearing years has implications for maternal health. The purpose of this study was to test whether partner satisfaction, partner conflict, and their interaction predicted maternal cardio-metabolic health at 12-months postpartum. Women were recruited in 5 U.S. sites. Partner conflict and satisfaction were measured at 6-months postpartum, and cardio-metabolic indicators (blood pressure, waist–hip ratio, glycosylated hemoglobin, total cholesterol:HDL ratio) were assessed at 6- and 12-months. Cardio-metabolic indices were scored continuously (CM risk) and using clinical risk cutoffs (CM scores). A significant conflict-by-satisfaction interaction emerged for the CM risk, $b(SE)$ = .043 (.016), p = .006, and CM scores, $b(SE)$= .089 (.028), p = .002, such that when partner satisfaction was low, low partner conflict was associated with poorer postpartum cardio-metabolic health. This is the first study to examine close relationships and cardio-metabolic health during the child-bearing years, an issue warranting further attention.

Keywords Partner relationship satisfaction · Relationship conflict · Cardio-metabolic health · Postpartum

Electronic supplementary material The online version of this article (https://doi.org/10.1007/s10865-018-9947-2) contains supplementary material, which is available to authorized users.

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Abbreviations

BMI	Body mass index
CCHN	Community Child and Health Network
DAS	Dyadic Adjustment Scale
DBP	Diastolic blood pressure
DBS	Dried blood spot
FPL	Federal poverty line
HDL	High density lipoprotein
HPA	Hypothalamic-pituitary-adrenal
MAP	Mean arterial pressure
SBP	Systolic blood pressure
WHR	Waist–hip ratio

Introduction

Metabolic syndrome is a pre-cardiovascular disease state defined by adiposity, dyslipidemia, hypertension, and insulin resistance (Cornier et al., 2008; Grundy, 2015). The prevalence of metabolic syndrome has been increasing in the U.S. over the last few decades, especially among women of child-bearing age (Mozumdar & Liguori, 2011; Ramos & Olden, 2008). This is concerning given that pregnancy requires cardio-metabolic adaptations (Rodie et al., 2004), including a degree of insulin resistance, hyperlipidemia, weight gain, and increased blood volume, and these adaptations may be compromised or difficult to sustain when cardio-metabolic risk factors exist prior to a pregnancy. Returning to pre-pregnancy cardio-metabolic physiologic functioning after the birth of a child is also important, as it predicts decreased risk of cardio-metabolic complications during subsequent pregnancies, i.e. conditions such as preeclampsia or gestational diabetes (Rodie et al., 2004). Returning to pre-pregnancy cardio-metabolic physiologic function also predicts reduced risk for future cardiovascular disease overall (Rodie et al., 2004). Thus, identifying the factors that contribute to postpartum cardio-metabolic status has possible implications for the prevention of cardiovascular disease risk in women during the child-bearing years and over the lifespan.

In the general population, close relationships have potent influences on health, including such outcomes as cardio-metabolic risk, metabolic syndrome, and cardiovascular disease morbidity and mortality (Holt-Lunstad et al., 2010). Evidence suggests that partner relationship quality—defined as global evaluations or perceptions of the marital or partner relationship—is especially relevant for health in adult men and women (Kiecolt-Glaser & Newton, 2001; Robles & Kiecolt-Glaser, 2003; Robles et al., 2014), as well as for women during pregnancy and the postpartum period (Dunkel Schetter, 2011). Partner relationship quality, however, is typically conceptualized along a single dimension, with high and low quality relationships representing polar opposites (Robles et al., 2014). Using this unidimensional approach in non-pregnant samples of men and women, poorer marital quality has been associated with greater inflammation, increased blood pressure and heart rate, and increased risk for metabolic syndrome and overt cardiovascular disease (Kiecolt-Glaser & Newton, 2001; Robles & Kiecolt-Glaser, 2003; Robles et al., 2014). However, very few studies have examined associations between partner relationship quality and indicators of physical health during the postpartum period. An exception is a study of 431 expecting couples where poor intimate partner relationship quality was associated with poorer self-reported prenatal general health, well-being and more somatic and psychological symptoms (Brown, 1994).

A unidimensional conceptualization of relationship quality treats positive and negative aspects of close relationships as opposite ends of a single continuum. Research shows, however, that positive and negative aspects of close relationships are independent, although negatively correlated, phenomena (Abbey et al., 1985; Gable & Reis, 2001; Okun & Lockwood, 2003). Accordingly, close relationships can be characterized by the degrees of both positive and negative aspects. Well-functioning relationships are typically thought of as being high in positive and low in negative aspects, whereas poorly-functioning relationships as low in positive and high in negative aspects. However, a relationship can also be both highly supportive and highly conflictual (i.e. high positive and high negative), which is referred to as an "ambivalent" relationship. Or, alternatively, a relationship can be lacking in both support and conflict (i.e. low positive and low negative), which has been termed an "indifferent" relationship. Among these, the predominate focus in the literature has been on the health effects of "ambivalent" close relationships (Fincham & Linfield, 1997). For example, researchers have found that in middle-aged or older adults, "ambivalent" marital relationships (high negative, high positive) were associated with greater coronary artery calcification (Uchino et al., 2014), greater ambulatory blood pressure (Birmingham et al., 2015), and greater levels of inflammatory markers (Uchino et al., 2013).

Only one prior study has specifically assessed positive and negative aspects of partner relationship quality during the child-bearing years. In a sample of 90 pregnant women, when positive partner relationship characteristics (support and closeness) were low, low negative partner relationship features (conflict) were associated with greater inflammation towards the end of pregnancy (Ross et al., 2017). That is, an "indifferent" pattern of partner relationships (low positive, low negative) was associated with inflammatory biomarkers usually characterizing poorer health. This contrasts with previous research in adult samples which has detected associations mainly for "ambivalent" (high positive, high negative) partner relationships. As such, the present study sought to determine which of these patterns predicted cardio-metabolic health in another child-bearing sample.

The purpose of this study was to determine whether partner relationship satisfaction, partner conflict, and their statistical interaction predicted cardio-metabolic risk between 6- and 12-months postpartum. We hypothesized that: (1) Greater relationship satisfaction in mothers would predict lower postpartum cardio-metabolic risk; (2) relationship conflict as reported by mothers would predict greater maternal postpartum cardio-metabolic risk; and (3) based on the prior study of child bearing women, relationship satisfaction and conflict would interact such that, in the presence of relatively low partner satisfaction, low partner conflict would predict the greatest postpartum cardio-metabolic risk.

Methods

Participants

The sample consisted of 593 women from the Community Child and Health Network (CCHN) cohort, which was funded by the Eunice Kennedy Shriver National Institute for Child Health and Human Development (NICHD). Women were recruited immediately following the birth of a child from one of 5 sites (2008–2010): Los Angeles, CA; Washington, DC; Baltimore, MD; Lake County, IL; and seven counties in rural eastern North Carolina. Study sites were selected at time of funding based on epidemiological evidence of maternal and child health disparities, and population characteristics reflective of high proportion of low income and racial/ethnic minority groups with high morbidities. Eligibility criteria included being between 18 and 40 years of age, self-identification as either White, Black or Latina, English or Spanish-speaking, residence in target zip code for at least 6 months, currently having 4 or fewer children, and no intention to be surgically sterilized after the current birth (BeLue et al., 2014). Participants provided informed, signed consent to participate, and all protocols followed Declaration of Helsinki procedures. Study procedures and protocols were reviewed and approved by the Institutional Review Boards of all community and academic institutions associated with CCHN (Ramey et al., 2015).

Procedure

Women completed structured interviews in their homes at 1-, 6- and 12-months postpartum. Partner relationship quality was assessed at 6 months postpartum using the Dyadic Adjustment Scale (DAS; see below). Cardio-metabolic indicators were assessed at 6- and 12-months postpartum, and consisted of resting blood pressure, waist and hip circumference, and cholesterol and glycosylated hemoglobin values obtained from dried blood spots (DBS; see below). A total of 1420 women completed partner relationship quality questions at 6-months postpartum. Women who had been diagnosed with a cardio-metabolic disease during the previous pregnancy, specifically preeclampsia, gestational diabetes, or gestational hypertension, were excluded (n = 306) due to the long-term effects these disease may have on maternal cardio-metabolic physiology (Rodie et al., 2004; Ross et al., 2018), and because our primary interest was in postpartum processes in healthy women. Of the remaining 1212 women, 899 had cardio-metabolic data at 6- and 12-months postpartum. The final sample consisted of 593 women with data on all relevant variables. Excluded women were more likely to have had a higher pre-pregnancy BMI, $t(1515) = 3.33$, $p = .001$, be younger, $t(2104) = -2.77$, $p = 006$, be Black race, $\chi^2(1) = 127$, $p < .001$, or Latina ethnicity, $\chi^2(1) = 30.5$, $p < .001$, and not be living with or married to their partner, $\chi^2(1) = 127$, $p < .001$.

Partner satisfaction and conflict

Partner relationship quality was assessed with the Dyadic Adjustment Scale (DAS) at 6-months postpartum (Spanier, 1976). The DAS consists of 32 questions that assess perceived agreement with partner in important domains such as finances and sexual relations; frequency of behaviors like confiding and arguing; commitment; and happiness with the relationship. The standard scoring for this instrument yields four subscales: consensus, cohesion, affective expression, and satisfaction. A subset of items from the "satisfaction" subscale (e.g., discussing separation or divorce, getting "on each other's nerves," and regret about being in the relationship) tap negative components of the partner relationship, and have been used as an index of partner negativity elsewhere (e.g., Kimmel et al., 2000). We used exploratory factor analysis [maximum likelihood, non-orthogonal (oblimin) rotation; (SPSS; IBM, 2016)] to determine whether items from the DAS "satisfaction" subscale contained a negative or conflict domain. A two factor solution emerged explaining 46% of the total variance in the 10 items. The first factor was defined by three items assessing partner conflict: Leaving the house after a fight, frequency of arguments, and getting on each other's nerves (Factor loadings = .424–.781, Mean = 0.642), Cronbach's $\alpha = .69$. The second factor was defined by 7 items: How often you think things are going well between you and your partner; how often you confide in your partner; how often you kiss your partner; how happy you are in your relationship; how committed you are to your relationship; and, reverse coded, how often you consider terminating the relationship; and regret being in this relationship (Factor loadings = .568–.708, Mean = 0.629), Cronbach's $\alpha = .73$. All item cross-loadings for both factors were <.238, Mean = 0.146. Although conceptually different from the original DAS "satisfaction" subscale, we chose to label the second factor 'partner satisfaction' given that the 7 items identified seem to tap contentment or satisfaction with the partner relationship. The two factors were significantly and negatively correlated, $r = -.65$.

Separate conflict and satisfaction scales were calculated by summing responses on the relevant items. Values for conflict scores ranged from 5 to 15, and satisfaction scores from 7 to 35, with higher values indicating greater conflict or satisfaction. A satisfaction-by-conflict interaction term was calculated by standardizing conflict and satisfaction, and taking the product of the standardized variables. For descriptive purposes only, median splits of the satisfaction and conflict variables were used to determine the percentage of participants that fell into each of the traditionally-defined categories of close relationship quality. The majority of women (43%) were in "high quality" partner relationships (high satisfaction, low conflict), 29% in "low quality" relationships (low satisfaction, high conflict), 15% in "ambivalent" relationships (high satisfaction, high conflict), and 12% in "indifferent" relationships (low satisfaction, low conflict).

Postpartum cardio-metabolic health

Cardio-metabolic indicators were assessed by study personnel at 6- and 12-months postpartum. Waist circumference was measured at the navel using a cloth measuring tape and recorded to the nearest cm. Measurements were repeated and the average of the two measurements was used. Waist–hip ratio (WHR) was calculated by dividing the waist measurement by the hip measurement. Blood pressure (systolic and diastolic) was measured using a portable, automatic blood pressure machine (HEM-711DLX or HEM-907XL Pro blood pressure monitor, OMRON, Kyoto, Japan). Systolic (SBP) and diastolic blood pressure (DBP) values were then used to calculate mean arterial pressure (MAP) using the following formula: MAP = 1/3 SBP + 2/3 DBP.

A non-fasting blood sample was collected using a dried blood spot (DBS) card. A finger was lanced and capillary blood collected on filter paper. DBS cards were allowed to dry for 30 min, and then stored at − 30 °C prior to shipment to ZRT Laboratory (Beaverton, OR) for analysis. DBS were assayed for glycosylated hemoglobin, total cholesterol and high density lipoproteins (HDL). Glycosylated hemoglobin can be used as a proxy for fasting blood glucose, and represents average red blood cell exposure to glucose over the previous 3 months. Percentage of glycosylated hemoglobin out of total hemoglobin is assessed using an immunoturbidimetric assay, coefficients of variation (CVs) < 8.5. Greater values indicate greater average blood glucose. Both non-fasting total cholesterol and HDL (mmol/L) were assessed via enzymatic assay, CVs < 7.1 and 8.7, respectively. A ratio of total cholesterol:HDL was calculated by dividing total cholesterol values by total HDL values, with higher values indicating greater cardiovascular disease risk (Millan et al., 2009).

In addition to the individual cardio-metabolic indicators [WHR, systolic blood pressure (SBP), diastolic blood pressure (DBP), total cholesterol:HDL ratio, and glycosylated hemoglobin], two cardio-metabolic composite scores were calculated to provide an indication of overall postpartum cardio-metabolic health. First, a continuous cardio-metabolic health index was calculated from MAP, WHR, total cholesterol:HDL ratio and glycosylated hemoglobin by standardizing each indicator across participants and assessments, then calculating the average of the four standardized indicators at 6- and 12-months postpartum. Higher continuous scores indicate poorer postpartum cardio-metabolic health. This approach to conceptualizing cardio-metabolic health has been extensively used elsewhere (e.g., Adegboye et al., 2011; Brage et al., 2004; Damsgaard et al., 2014; Eisenmann, 2008; Ekelund et al., 2005; Franks et al., 2004; Ross et al., 2011).

A second cardio-metabolic index was calculated from cardio-metabolic indicator clinical cut-offs, with clinical thresholds defined as WHR $\geq$ .80, glycosylated hemoglobin $\geq$ 5.7%, total cholesterol:HDL $\geq$ 3.5, and systolic blood pressure $\geq$ 140 mmHg or diastolic blood pressure $\geq$ 90 mmHg (Hostinar et al., 2017). A cardio-metabolic clinical cut-off score was calculated by taking the number of four cardio-metabolic indicators on which the participant was above the clinical cut-offs, yielding a score from 0 to 4 with 4 indicating poorer postpartum cardio-metabolic health.

Covariates

Possible covariates were selected for theoretical reasons and based on a review of the literature. They were number of weeks between 6- and 12-month assessments, demographic characteristics (maternal age at study entry, race/ethnicity, and adjusted per capita household income), parity, relationship with baby's father (married or cohabiting), breastfeeding and change in relationship status between 6- and 12-months postpartum. These were included in analyses if they were significantly associated with any of the cardio-metabolic indicators at either 6- or 12-months postpartum. Parity and change in partner relationship were the only variables not associated with any of the cardio-metabolic markers, and were thus dropped.

Participants self-identified as either African American/Black, Latina/Hispanic, or non-Latina White at study entry. Race/ethnicity was dummy coded (Black vs. other, Latina vs. other). During the 1-month postpartum interview, participants reported their pre-tax household income in the previous year. Adjusted per capita household income was then calculated based on number of individuals in the home and the study site. Participants reported marital and cohabitation status with their partner at 6-months postpartum, and were classified as either married to or cohabitating with their partner (1), or not married to or cohabitating with their partner (− 1). Breastfeeding was assessed at 6- and 12-months postpartum, and women were coded as 'never breastfed,' 'breastfed but stopped before 6 months postpartum,' and 'breastfed up to or past 6 months postpartum.'

Analytic strategy

All analyses were run using SPSS (IBM, 2016). First, data were inspected for outliers and normality prior to analyses. Outliers were defined as values greater than ± 3 standard deviations from the respective means, and were Winsorized to ± 3 standard deviations. Paired sample *t*-tests were used to determine whether postpartum cardio-metabolic indicators or the summary cardio-metabolic risk score changed between 6- and 12-months postpartum. No evidence of multicollinearity was detected.

Separate linear regression models were run to test associations between partner relationship satisfaction, partner conflict, and the satisfaction-by-conflict interaction term with 12 month postpartum (1) individual cardio-metabolic indicators (SBP, DBP, WHR, total cholesterol:HDL ratio, and glycosylated hemoglobin), (2) continuous cardio-metabolic health index, and (3) cardio-metabolic clinical index. All models adjusted for 6-month postpartum levels of the dependent variables in order to evaluate change, and for weeks between the two assessments, age, race/ethnicity, adjusted per capita household income, breastfeeding and partner marital/cohabitation status.

Significant interactions were decomposed using the Johnson-Neyman technique (Preacher et al., 2003). Regression coefficients and covariances are used to calculate (1) predictor on outcome simple slopes for different values of the moderator, and (2) regions of significance, or moderator values at which regression of the predictor onto outcome variable shifted from non-significant to significant. Partner conflict was entered as the predictor and partner satisfaction as the moderator.

Results

Sample characteristics

Sample descriptive statistics are presented in Table 1, and correlations between partner relationship quality variables and cardio-metabolic indicators in Table S1. Participants were 25.8 ± 5.74 years of age at study entry, about half were Black (49%), and 60 percent were married to or living with their partner. Relationship status (married, cohabiting) was relatively stable on average in the sample between 6 and 12 months postpartum (94% unchanged status).

Descriptive statistics for the cardio-metabolic indicators are presented in supplementary Table S2. Paired-sample *t*-tests were used to assess average change between 6 and 12 months postpartum for each cardio-metabolic indicator and the overall cardio-metabolic risk index. The ratio of total cholesterol to HDL, $t(504) = -2.64$, $p = .008$, and overall cardio-metabolic health, $t(744) = -2.81$, $p = .005$, significantly decreased on average over the follow-up, as would be expected.

Partner satisfaction, conflict and individual cardio-metabolic indicators

Results from linear regression models predicting 12-month postpartum cardio-metabolic indicators with partner relationship satisfaction, partner conflict and their interaction, and adjusted for covariates and 6-month postpartum cardio-metabolic indicators, are presented in Table 2. Higher partner satisfaction was associated with lower 12-month postpartum MAP, relative to 6-month MAP levels, $b = -1.21$, $SE = .400$, $p = .003$. Partner satisfaction was not associated with 12-month postpartum total cholesterol:HDL ratio, WHR, or glycsolated hemoglobin, p's $> .121$. Partner conflict was also not associated with 12-month postpartum MAP, WHR, cholesterol:HDL or glycosylated hemoglobin, p's $> .192$.

A significant satisfaction-by-conflict interaction predicting 12-month postpartum WHR was detected, $b = .004$, $SE = .002$, $p = .048$. When the interaction was probed, it was revealed that simple slopes became significant at values outside the range of possible values for partner relationship satisfaction (scores above 80 or below − 50, for a scale with possible scores ranging from 7 to 35). As such, this interaction could not be interpreted. The interaction term was not associated with 12-month postpartum MAP, total cholesterol:HDL ratio, or glycosylated hemoglobin, p's $> .103$ (Table 2).

Table 1 Sample characteristics (n = 593)

Variable	% or Mn (SD)	Variable	%
Weeks between assessments	25.2 (6.72)	Relationship ended over follow-up	6
Pre-pregnancy BMI (kg/m^2)	26.4 (6.50)	Race/ethnicity	
		Black	49
Age (years)	25.8 (5.74)	Latina	27
Primiparous	46%	White	24
		Poverty group	
Currently employed	47%	Poor	42
Non-drinkers	67%	Near poor	28
Non-smoker	82%	Low income	31
		Breastfeeding	
Married/cohabitating	60%	Never breastfed	27
Partner satisfaction	29.2 (4.82)	Breastfed, stopped before 6 mo PP	50
Partner conflict	7.56 (2.37)	Breastfed, up to/past 6 mo PP	23

PP postpartum period

Table 2 Associations between partner satisfaction, conflict, and the conflict-by-satisfaction interaction term and 12 month cardio-metabolic indicators, controlling for baseline indicators or indices, demographics, breastfeeding and marital/cohabitation status

Outcome	Predictor	b	SE	*p*
Mean arterial pressure	Conflict	− .518	.396	.192
	Satisfaction	− 1.21	.400	.003
	Conflict × satisfaction	.349	.258	.176
Glycosylated hemoglobin	Conflict	− .033	.032	.304
	Satisfaction	− .044	.033	.182
	Conflict × satisfaction	.029	.021	.160
Total cholesterol:HDL ratio	Conflict	− .074	.083	.373
	Satisfaction	− .134	.086	.121
	Conflict × satisfaction	.089	.055	.103
Waist–hip ratio	Conflict	.001	.004	.730
	Satisfaction	− .002	.004	.586
	Conflict × satisfaction	.004	.002	.048*
Continuous cardio-metabolic index	Conflict	− .008	.024	.752
	Satisfaction	− .062	.024	.010
	Conflict × satisfaction	.043	.016	.006
Cardio-metabolic clinical cut-off scores	Conflict	− .014	.043	.740
	Satisfaction	− .080	.044	.068
	Conflict × satisfaction	.089	.028	.002

*When the interaction was decomposed, boundaries of significant slopes were outside the range of possible values for partner satisfaction. As such, this interaction cannot be interpreted

Partner satisfaction, conflict and continuous cardio-metabolic index

Linear regression models were run predicting the continuous 12-month postpartum cardio-metabolic index as described above. Partner satisfaction was associated with cardio-metabolic index values, such that higher satisfaction with the partner relationship was associated with better overall 12-month postpartum cardio-metabolic health relative to baseline values, $b = -.062$, $SE = .024$, $p = .010$. Partner conflict, however, was not associated with the 12-month postpartum continuous cardio-metabolic index, $b = -.008$, $SE = .024$, $p = .752$. Independent effects were further qualified by a significant interaction, $b = .043$, $SE = .016$, $p = .006$ (Table 2). Decomposing the interaction revealed that, when partner satisfaction was low (< 24.2 partner satisfaction score), a significant association emerged between partner conflict and the 12-month postpartum continuous cardio-metabolic index, $b = -.052$, $SE = 026$, $p = .05$, such that at low levels of partner satisfaction, lower partner conflict was associated with poorer 12-month postpartum cardio-metabolic health (Fig. 1a). This result is consistent with an "indifferent" pattern of partner relationship (low satisfaction, low conflict).

Partner satisfaction, conflict and cardio-metabolic clinical cut-off scores

As a final step, linear regression models predicting 12-month postpartum cardio-metabolic clinical cut-off scores were run (Table 2). Neither partner satisfaction, $b = -.014$, $SE = .043$, $p = .740$, nor partner conflict, $b = -.080$, $SE = .044$, $p = .068$, were associated with 12-month postpartum cardio-metabolic clinical cut-off scores. However, a significant interaction emerged, $b = .089$, $SE = .028$, $p = .002$. Again, when partner satisfaction was relatively low (< 25.1 partner satisfaction score), an association emerged between partner conflict and number of cardio-metabolic clinical cut-offs, $b = -.090$, $SE = .046$, $p = .05$. Again, consistent with an "indifferent" pattern of partner relationships, when partner satisfaction was low, lower partner conflict was associated with higher number of cardio-metabolic clinical cut-offs met (Fig. 1b).

Discussion

The purpose of this study was to determine whether partner relationship satisfaction, partner conflict, and their interaction predicted changes in cardio-metabolic health between 6- and 12-months postpartum in a diverse sample of women from five U.S. regions. Contrary to hypotheses,

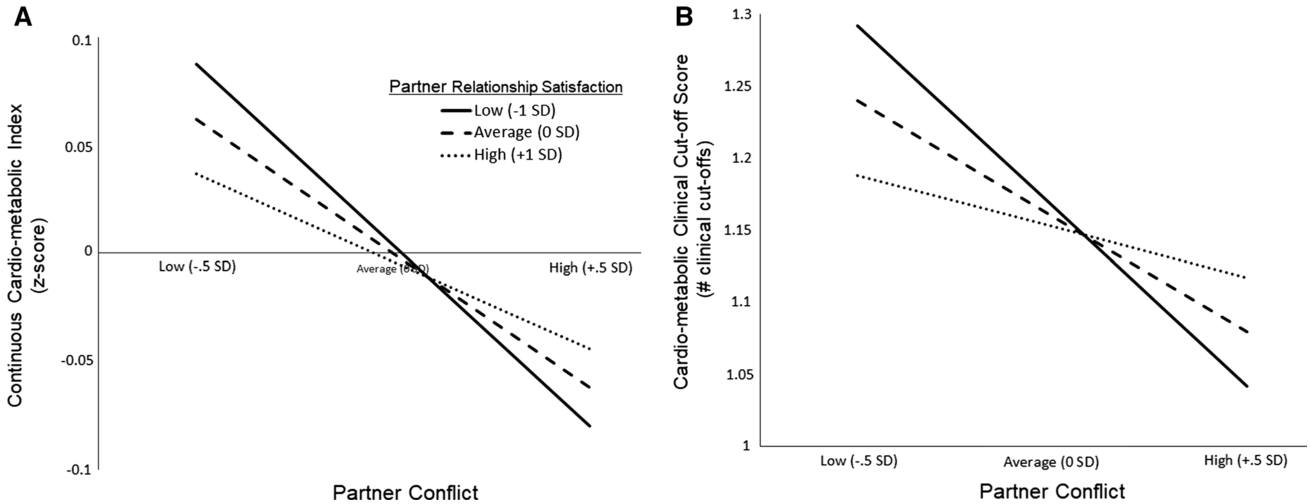

Fig. 1 Simple slopes of the significant satisfaction-by-conflict interaction predicting the continuous cardio-metabolic index (**a**) and the cardio-metabolic clinical cut-off scores (**b**). When partner satisfaction was low, lower partner conflict was associated with poorer 12-month postpartum cardio-metabolic health, as indicated by continuous cardio-metabolic index values (**a**) and number of cardio-metabolic clinical cut-offs met (**b**)

neither partner conflict nor partner satisfaction were associated with postpartum cardio-metabolic health indicators. However, a significant interaction between satisfaction and conflict was detected, such that partner relationships that were reported by mothers to be relatively low in both conflict and in satisfaction (i.e. "indifferent" relationships) were associated with poorer 12-month postpartum cardio-metabolic health, adjusting for 6-month postpartum health and a number of covariates (demographics, breastfeeding and partner relationship status). Specifically, partner relationship quality was associated with both a continuous index of cardio-metabolic health and a clinical threshold score, each calculated from blood pressure, WHR, total cholesterol:HDL ratio and glycosylated hemoglobin. Thus, for relatively young, child-bearing women, partner relationship quality may have implications for understanding both sub-clinical changes in a continuous index of cardio-metabolic health and for the number of clinical cardio-metabolic conditions met.

Prior research in middle-aged and older adults indicated that "ambivalent" partner relationships (high positive and negative) predicted poorer cardio-metabolic health, including greater coronary artery calcification (Uchino et al., 2014), ambulatory blood pressure (Birmingham et al., 2015), and peripheral inflammation (Uchino et al., 2013). Here, we found a contrasting effect: Partner relationships relatively lacking in both satisfaction and conflict ("indifferent") were associated with more unfavorable health outcomes. Intuitively, poorer quality close relationships, or those low in satisfaction and high in conflict, would be expected to be the most detrimental to health. In this study, however, and consistent with one other study (Ross et al., 2017), low satisfaction in combination with a relative *lack of* conflict was associated with poorer postpartum cardio-metabolic health.

The child-bearing years may provide a unique context in which a woman's partner relationship has potentially powerful effects. "Indifferent" partner relationships may indicate a lack of partner engagement, reflecting withdrawal, neglect or apathy that could precede separation or divorce (DeLongis et al., 2004; Fincham & Linfield, 1997; Mattson et al., 2013; Vinokur & van Ryn, 1993). As such, a general lack of partner engagement during postpartum months—both positively and negatively—may be more potent for longer term maternal health than partner conflict, which can be thought of as a byproduct of any relationship, and is not, in and of itself, detrimental if well managed or not extreme in severity. Given the documented centrality of the partner relationship during the child-bearing years (e.g., Dunkel Schetter, 2011), partner relationships perceived as "indifferent" may be particularly distressing, with subsequent downstream consequences for health.

Interestingly, partner conflict did not have a main effect on postpartum cardio-metabolic health, whereas higher partner satisfaction was associated with lower MAP and the continuous cardio-metabolic index, although not any of the other cardio-metabolic indicators or the clinical cut-off scores. This is consistent with the one other recent pregnancy study that assessed positive (support, closeness) and negative (conflict) aspects of partner relationships, and their interaction, and found that positive partner relationship aspects (social support, closeness) were more consistently associated with inflammatory markers (Ross et al., 2017). Past research focusing only on partner conflict has reported associations between increased marital conflict and poorer child development outcomes, compromised parent–child bonding (Essex et al., 2003; Owen & Cox, 1997; Repetti et al., 2002; Troxel & Matthews, 2004) and increased maternal depressive symptomatology over pregnancy and the postpartum period (Dennis & Ross, 2006; Hassert et al., 2015; Kingsbury et al., 2015; Lau, 2011; Lau & Keung, 2007; Lau & Wong, 2008; Owoeye et al., 2006). Another body of research has additionally documented the detrimental consequences of partner abuse in the context of pregnancy (Fikree & Bhatti, 1999; Hill et al., 2016; Mcfarlane et al., 1992; Nayak & Al-Yattama, 1999). Collectively, this evidence highlights the important role that partner conflict plays in the context of maternal mental health, child development and early family processes. However, little work has examined physical health of mothers in relation to close relationship conflict.

That close relationship quality predicts changes in physiological indicators during the child-bearing years is consistent with two other studies of pregnant and postpartum women (Jewell et al., 2015; Ross et al., 2017). Pregnancy and the postpartum period are represented by dynamic and changing biological states. As such, it might be possible that quality of close relationships during this period plays an important role in a woman's ability to successfully manage those physiological adaptations. This hypothesis has, however, not been tested, due to the paucity of research on associations between close relationships and maternal neuroendocrine, cardio-metabolic and/or immune function following the birth of a child (Hamelin-Brabant et al., 2015). Future research is needed to better understand how close relationships affects physical health indicators such as cardio-metabolic risk during this dynamic period.

In addition to exploring associations between partner relationship quality and changes in postpartum cardio-metabolic health indicators, we also report overall changes in these indicators between 6- and 12-months postpartum. Few studies document normative changes in cardio-metabolic physiology over the longer postpartum period in humans. The majority of the available research has focused on postpartum weight (e.g., Magriples et al., 2015; Yakusheva et al., 2017), showing decreases in weight over the postpartum period as the norm. Waist–hip ratios, however, did not significantly change in this sample, which is consistent with trends observed in another cohort of diverse, low-income women followed over the first year postpartum (Gould Rothberg et al., 2011). This trend possibly reflects the unique challenges faced by lower socioeconomic status women, such as ability to breastfeed, ready access to healthy foods, and opportunities to exercise. In addition, two studies suggested that blood pressure may decrease slightly up to 9 months postpartum (Groer et al., 2013; Parikh et al., 2017), although significant changes in MAP were not observed here. HDL cholesterol has been reported to decrease up to 2 years postpartum, although trends may vary by parity (Gunderson et al., 2004), and these findings are consistent with decreases in total cholesterol:HDL ratios here. We could find only one study that reported trends for blood glucose, which reported overall decreases up to 9 months postpartum (Parikh et al., 2017). Here, glycosylated hemoglobin did not significantly change over the follow-up. Altogether, these studies suggest a general decrease in cardio-metabolic indicators over the postpartum period, which is consistent with the significant decrease in cardio-metabolic risk observed here. Nonetheless, future research is required to better understand normative changes in cardio-metabolic indicators over the first year postpartum. Such investigation has potentially important implications for women's health during subsequent pregnancies and in general.

Limitations to the study include our conflict subscale scored from the DAS. Although other studies have also extracted conflict subscales from the DAS (e.g., Kimmel et al., 2000), it was not created with the intention of assessing partner conflict. Ideally these findings would be replicated using measures designed specifically to assess positive and negative partner relationship quality. A second limitation is that partner relationship quality was assessed only once. Partner satisfaction may fluctuate over the postpartum period (Lawrence et al., 2008), thus follow-up studies can examine these issues over a longer time span. Third, our sample consisted of a population of poor to middle income women, a population that is understudied in health research. Nonetheless, it remains unclear if these findings generalize to individuals of higher socioeconomic status. Fourth, women were excluded from our analytic sample if they had been diagnosed with a pregnancy cardio-metabolic disease, due to the possible long-term effects these diseases could have on maternal postpartum cardio-metabolic health. Although pregnancy cardio-metabolic diseases usually resolve with the pregnancy, evidence suggests that sub-clinical physiological damage can persist into the postpartum period and increase risk for future cardio-metabolic disease (Rodie et al., 2004; Ross et al., 2018). It is possible that associations between partner relationship quality and postpartum cardio-metabolic health could be altered in the context of existing cardio-metabolic damage. Additional research is needed to explore how these associations unfold in samples affected by pregnancy cardio-metabolic disease. In addition, women not included in our analytic sample were more likely not to be living with or married to their partner, which suggests possible differences in partner relationship dynamics or quality. Future research can investigate the extent to which associations between partner relationship quality and maternal postpartum cardio-metabolic health differ for women who are not cohabiting with or married to their partner. Finally, issues of causality deserve mention. Although our analytic approach suggests that partner relationship quality was associated with cardio-metabolic risk at a later time, independent of baseline cardio-metabolic risk, it is possible that poorer cardio-metabolic health may drive poorer partner relationship quality, or that other unaccounted for factors may be driving this association.

In sum, this is one of very few studies to examine links between partner relationship quality and physiological markers and health risks, and the first on maternal cardio-metabolic risk. Understanding how social relationships influence physiology in the reproductive years in women can help optimize maternal and child health. These findings highlight the potential importance of considering both positive and negative aspects of mothers' close relationship quality, and the partner relationship in general, for maternal health in the year following the birth of a child and thereafter.

Acknowledgements This study was conducted by Community Child Health Network (CCHN) through cooperative agreements with the Eunice Kennedy Shriver National Institute of Child Health and Human Development [UHD44207, U HD44219, U HD44226, U HD44245, U HD44253, U HD54791, U HD54019, U HD44226-05S1, U HD44245-06S1, R03 HD59584] and the National Institute for Nursing Research [U NR008929]. K. Ross is supported through the National Institute for Health [R01 HD073491] and Eunice Kennedy Shriver National Institute of Child Health and Human Development [R01 HD072021-01A1].

Compliance with ethical standards

Conflict of interest Kharah M. Ross, Christine Guardino, Calvin J. Hobel, and Christine Dunkel Schetter declare that they have no conflict of interest.

Human and animal rights and Informed consent All procedures were in accordance with the ethical standards of the institutional research committees and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants included in the study.

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