


# The impact of maternal flood-related stress and social support on offspring weight in early childhood

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**Abstract** The current study examined the moderating role of social support in the association between prenatal maternal stress (PNMS) and childhood body mass index (BMI) in the context of the Iowa floods of 2008. In addition, the mediating role of offspring birthweight was examined in the association between PNMS and childhood BMI. We recruited women from eastern Iowa who were pregnant in 2008 when disastrous floods occurred. Self-report measures of PNMS and cognitive appraisal of the flood's consequences were obtained shortly after the disaster. Social support was assessed during pregnancy. Offspring anthropometric measures were collected at birth and 30 months. Moderated mediation results indicated that greater PNMS predicted greater BMI at age 30 months through effects on higher birthweight as a mediator, but only for participants with low social support. High social support (satisfaction or number) buffered the effect of PNMS or a negative appraisal of the flood on birthweight. The combination of high PNMS or a negative appraisal of the flood's consequences and low social support resulted in higher offspring birthweight, which predicted greater BMI at 30 months. Providing strong social support to pregnant women following

a stressor might buffer the effects of PNMS on offspring birthweight and later obesity.

**Keywords** Prenatal maternal stress · Cognitive appraisal · Social support · Birthweight · Natural disaster · Trauma · Childhood weight

## Abbreviations

BMI Body mass index  
PNMS Prenatal maternal stress

Worldwide, 42 million children under 5 years of age are overweight (UNICEF, WHO, The World Bank Group 2016) and 17% of US children aged 2–19 years are obese (Ogden et al. 2014). Seventy-seven percent of obese children remain obese as adults (Freedman et al. 2001). Thus, childhood obesity can have long-lasting health implications (Franks et al. 2010).

The intrauterine environment plays an important developmental role in obesity risk (Huang et al. 2007; Heindel and vom Saal 2009), both directly through effects on central regulators of metabolism, and through effects on early growth patterns that alter the child's long-term developmental trajectory (Gluckman et al. 2008). One factor linked to increased obesity risk is exposure to prenatal maternal stress (PNMS). Animal studies have linked maternal stress to offspring obesity via effects of maternal stress hormones on the developing fetus (Drake et al. 2007) and through epigenetic changes in the placenta and fetus (Gluckman and Hanson 2008). Similar associations have been observed in human research. Studies in Denmark found that children exposed to PNMS had higher prevalence of overweight and higher body mass index (BMI) than unexposed children (Li et al. 2010). Furthermore, disaster-related stress has been associated with early incidence

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of obesity (Dancause et al. 2012) and higher levels of central adiposity in childhood and adolescence (Liu et al. 2016). Further studies are necessary to identify factors that moderate relationships between PNMS and childhood growth measures.

## Social support in pregnancy

Social support is defined as the extent to which an individual has reliable others that make the individual feel cared about and valued (Sarason et al. 1983). Perceived social support reflects two basic constructs: the number of available others and satisfaction with the available support (Sarason et al. 1983). The impact of social support on health has been explored extensively, with many studies indicating that those with more support have better health (Cohen and Syme 1985). A lack of social support in the perinatal period has been linked to depression (Norbeck and Tilden 1983; O'Hara and Swain 1996; Goodman and Tully 2009), pregnancy complications (Zachariah 2009), and offspring birthweight (Feldman et al. 2000; Nkansah-Amankra et al. 2010).

In addition to its main effects, social support can also act as a buffer against negative outcomes (Cohen and Wills 1985). For example, social support buffered against the effect of stressful life events in predicting postpartum depressive symptoms (Paykel et al. 1980; Turner 1981). Similarly, in a sample of perinatal women, "having more people provide positive feedback" buffered against effects of a "lack of money for basic needs" on depressive symptoms (Seguin et al. 1999). Other studies show interactions between social support and stressful life events in predicting pregnancy outcomes: women with low support and more stressful life events had more pregnancy complications and negative infant outcomes (Norbeck and Tilden 1983). Thus, social support might also be expected to act as a buffer in the association between PNMS and childhood obesity.

## The current study

In mid-June of 2008, Iowa faced its most damaging flooding in over 50 years. Eighty-five of Iowa's 99 counties were declared disaster areas. By the end of July 2008, 24 people had been killed by the floodwaters, and over 38,000 people were unable to live in their homes. In Cedar Rapids, the second largest city in Iowa, over 5000 homes were damaged, and the estimated total cost for repairs was \$10 billion.

The Iowa Flood Study seeks to examine the effects of PNMS due to the floods on child development. Results to date show that children exposed to higher levels of PNMS had higher total adiposity between ages 2½ and 4 years (Dancause et al. 2015). In addition, the amount of social

support, but not necessarily its adequacy, buffered women from developing postpartum depression following the disaster (Brock et al. 2014).

The current study examines offspring birthweight as a mediator in the previously observed effects of PNMS on childhood BMI at age 30 months and tests the extent to which prenatal maternal social support (number and/or satisfaction) buffers these effects. We hypothesized that birthweight would mediate the association between PNMS and offspring BMI at 30 months, and that social support would act as a buffer for PNMS.

## Method

### Participants and procedures

At the time of the floods, a study of social support and functioning in pregnant women was in progress (Nylen et al. 2013). After the floods began, participants in the ongoing study were invited to participate in another study to evaluate the impact of the flood on maternal and child outcomes (*Iowa Flood Study*).

Inclusion criteria were as follows: (a) age 18 years or older, (b) singleton pregnancy, (c) living in the region during the flooding, and (d) English speaking. Among 268 women in the study, 217 were pregnant prior to the onset of the flood. The remainder conceived within 3 months of the end of the flood ( $N = 13$ ) or were exposed within the first year after giving birth ( $N = 38$ ). Participants were recruited in several ways: brochures, press releases, and in person through clinics in areas affected by the flood.

For this study, we analyzed data from a subsample of 103 participants who completed measures of social support during pregnancy and whose children's birth and early childhood data were available. Mothers exposed to the flood postnatally were excluded from the current analyses.

## Measures

### Predictor measures

**Prenatal maternal flood stress** A scale of objective hardship due to the flood, the Iowa Flood 100 scale (IF100; <https://doi.org/10.1037/fam000027.supp>), was modeled on a similar measure used in a previous study of PNMS due to a natural disaster (Laplante et al. 2007). Items reflect four categories of exposure: threat to life or physical integrity, loss, scope of experience, and change. Each category score ranged from 0 to 25 (no exposure–high exposure). The IF100 total score reflects the sum of all category scores.

**Maternal subjective stress** The Peritraumatic Dissociative Experiences Questionnaire (PDEQ; Marmar et al. 1996) was used to measure peritraumatic dissociation. Each statement asks participants to rate the extent to which each dissociative occurrence (e.g., felt disconnected, blanked out) was experienced during or immediately after exposure to the flood. Items were rated on a five-point Likert scale (1 = not at all true, 5 = extremely true).

Two measures of distress due to the flood were used: the Peritraumatic Distress Inventory (PDI; Brunet et al. 2001) and the Impact of Events Scale-Revised (IES-R; Weiss and Marmar 1997). The PDI includes 13 items such as “I felt helpless to do more” and “I was horrified by what was happening.” Participants retrospectively rated the extent to which each symptom was experienced at the time of the flood on a five-point Likert scale (0 = not at all, 4 = extremely true), yielding a possible range of 0–52. The IES-R measures 22 items in three categories of posttraumatic stress disorder symptoms: intrusive thoughts, hyperarousal, and avoidance. Participants rated the extent to which each item described how they felt over the last 7 days in relationship to their experience of the flood. Each item is rated on a five-point Likert scale (0 = Not at all, 4 = Extremely), yielding a possible range of 0–88.

A composite measure of subjective stress (Maternal Subjective Stress)<sup>1</sup> was calculated from IES-R, PDI, and PDEQ total scores using Principal Components Analysis (PCA). The PCA resulted in a single factor that accounted for 76.36% of the overall variance in scores across the three original questionnaire measures. Maternal Subjective Stress was thus calculated from the equation:  $0.38$  (standardized IES-R) +  $0.388$  (standardized PDI) +  $0.376$  (standardized PDEQ).

**Cognitive appraisal of the flood consequences** Participants were asked, “If you think about *all of the consequences* of the flood on your family members and on yourself, would you say that the flooding has been: very negative, negative, neutral, positive, or very positive?” Because the number of participants with very negative, positive, and very positive ratings was low (7, 6, and 0, respectively) and because we were interested in the effect of having a negative versus non-negative cognitive appraisal, responses were grouped into negative versus neutral/positive for analyses.

**Timing of in utero exposure** The timing of flood exposure during pregnancy was defined as the number of days between the infant’s conception date, computed by subtracting 280 days from the due date, and June 15, 2008 (the peak of the floods). First trimester exposure corresponds to conception dates

falling between 0 and 91 days prior to June 15th; 2nd trimester, 92–182 days; and 3rd trimester, 182–280 days.

**Social support questionnaire (SSQSR)** The SSQSR (Sarason et al. 1987) is a six-item self-report measure of the size of one’s social support network and satisfaction with received support. Each question has two parts. The first assesses the number of individuals that the participant feels are available in each of the situations presented (e.g., “Who can you count on when you need help?”). Participants listed the initials and type of relationship (e.g., sister) for each person. The second part assesses the extent to which the participant is satisfied with the perceived support (Satisfaction score). Satisfaction is rated on a six-point Likert scale (1 = very dissatisfied, 6 = very satisfied). The size of an individual’s support network is derived by summing the total number of people listed across items and dividing by 6 (the number of items); higher values reflect larger support networks. Similarly, average level of satisfaction is derived by summing across items and dividing by six; higher scores reflect greater satisfaction. Internal consistency ranges from 0.90 to 0.93 on both scales.

**Offspring measures at birth** We recorded birthweight (grams) and gestational age (weeks) at birth from birth records.

#### *Additional covariates*

Number of previous pregnancies and maternal age were obtained from medical records. Household socioeconomic status (SES) was determined based on maternal and paternal education and occupational status using the Hollingshead Social Position criteria (Hollingshead 1975).

**Maternal depression** The Inventory for Depression and Anxiety Symptoms (IDAS; Watson et al. 2007) was used to measure depressive symptoms experienced over the past 2 weeks on a five-point Likert scale. The General Depression scale was used in analyses. Extensive psychometric data has established the reliability and validity of the IDAS (Watson et al. 2007, 2008).

#### *Outcome measure*

Offspring height (to the nearest 0.1 cm) and weight (to the nearest 0.1 kg) were measured at 30 months in the laboratory following standard anthropometric procedures and were used to compute BMI ( $\text{kg}/\text{m}^2$ ).

<sup>1</sup> Previous reports regarding this composite measure have used the acronym COSMOSS (COmposite Score for MOther’s Subjective Stress).

**Table 1** Demographic characteristics of current sample ( $N = 103$ )

Continuous variables	Minimum	Maximum	Mean	SD
BMI at 30 months, child	13.91	20.06	16.24	1.32
Birthweight (grams)	1946	4740	3546.36	459.67
Objective hardship	0	50.00	7.95	9.91
Maternal subjective stress	- 1.11	5.13	- 0.02	0.94
Social support number	1	9	4.14	1.81
Social support satisfaction	1	6	5.44	0.75
Gestational age (weeks)	35	42	39.29	1.31
Timing of exposure (days)	- 35.96	280.98	141.17	84.09
Age at birth, mother	18.12	41.86	30.34	5.03
Maternal depression	24	79	37	9.10
Categorical variables	Categories	$N$ (%)		
Cognitive appraisal of the flood consequences	Negative	47 (45.6)		
	Neutral + positive	56 (54.4)		
Child sex	Male	56 (54.4)		
	Female	47 (45.6)		
Previous pregnancies	Yes	66 (64.1)		
	No	37 (35.9)		
Socioeconomic status	Upper	48 (46.6)		
	Upper middle	48 (46.6)		
	Middle	3 (2.9)		
	Lower middle	4 (3.9)		

## Analyses

Demographic characteristics are reported in Table 1. Correlations between maternal characteristics (e.g., number of previous pregnancies) and offspring outcome variables were examined to determine covariates (see Table 2).

Analyses were conducted using SPSS, version 20. To test if social support moderated the mediation effect of PNMS on early childhood outcomes through birthweight, we used the PROCESS macro (Hayes 2013). The macro uses a bootstrapping method, resulting in a confidence interval around the index of moderated mediation. The coefficient corresponds to the moderated mediation effect. The effect is considered significant when the bootstrapping confidence interval excludes zero. PROCESS was also used to probe the moderation effect, giving information about the mediation effect at different social support levels. Ninety-five percent confidence intervals were computed using 10,000 resamplings. All reported coefficients are unstandardized. In the first part of the moderated mediation analyses, i.e., evaluating the effects of PNMS on offspring birthweight, we entered the stress measures (objective hardship, IF100; and either of the two subjective stress measures, labeled Maternal Subjective Stress or Cognitive Appraisal), as well as control variables including number of previous pregnancies, age of mother at birth, timing of in utero exposure, offspring sex, and offspring gestational age. In analyses with Maternal Subjective Stress as a predictor

variable, the Cognitive Appraisal variable was included as an additional control variable. Social support (either “number” or “satisfaction”) was entered into the model as a moderator variable, interacting with the stress measure to predict changes in birthweight. In the second part of the moderated mediation analyses, only the main PNMS predictor and birthweight were entered in the model to test their effects on childhood BMI.

## Results

Significant modest correlations were observed between objective stress, Maternal Subjective Stress, and Cognitive Appraisal ( $p < 0.001$ ). Each of these variables was also associated with SES ( $p < 0.05$ ). The only stress variable associated with childhood BMI was Maternal Subjective Stress ( $r = 0.21$ ,  $p < 0.05$ ). Objective stress was positively related to days of in utero exposure to the flood ( $r = 0.19$ ,  $p < 0.01$ ). A negative Cognitive Appraisal was correlated with higher offspring birthweight ( $r = - 0.13$ ,  $p < 0.05$ ). Given the priority of including flood-related variables as covariates, we elected to test whether the inclusion of maternal depression and SES significantly changed the results rather than to include those covariates in all models because neither variable was significantly related to children’s birthweights or BMIs.

**Table 2** Correlations among included measures

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. BMI, 30 months														
2. Birthweight	0.22*													
3. IF100	0.07	-0.11												
4. Maternal subjective stress	0.21*	0.02	0.46***											
5. Cognitive appraisal of the flood consequences	0.00	-0.14	-0.38***	-0.14										
6. SSQ, number	0.03	-0.07	-0.11	-0.03	0.00									
7. SSQ, satisfaction	0.06	-0.03	0.07	0.10	-0.05	0.39***								
8. Gestational age	0.04	0.40***	-0.12	0.02	0.11	-0.06	-0.16							
9. Days exposure	-0.06	0.08	0.21*	-0.05	-0.11	-0.08	0.17	-0.14						
10. Sex, child	-0.15	-0.19	-0.18	-0.15	0.02	-0.20*	-0.06	0.01	-0.06					
11. Previous pregnancies	-0.08	-0.21*	0.12	-0.01	0.08	0.21*	0.01	0.08	-0.12	0.01				
12. Maternal age	0.03	0.17	-0.09	-0.12	-0.03	0.05	-0.03	-0.05	0.14	-0.05	-0.23*			
13. SES	-0.06	-0.02	-0.13	-0.12	0.15	0.23*	0.17	-0.08	0.02	0.04	0.04	0.22*		
14. Maternal depression	-0.07	-0.00	0.08	0.29**	-0.10	-0.31**	-0.38***	-0.11	0.04	0.08	-0.04	0.07	-0.08	

IF100 Iowa Flood 100, SSQ Social Support Questionnaire, BMI body mass index, days exposure days of in utero exposure to the flood, SES socioeconomic status, Maternal depression IDAS-General Depression

\* $p < 0.05$ , \*\* $p < 0.01$ , \*\*\* $p < 0.001$

**Moderated mediation results**

Table 3 shows results from the regressions included in the significant moderated mediation analyses.

Social support number significantly moderated the effect of Cognitive Appraisal on birthweight (Fig. 1; index 0.0654, CI [0.0074; 0.1671]). For mothers with low social support, birthweight significantly mediated the effect of Cognitive Appraisal on BMI (mediation effect -0.2831, CI [-0.6287; -0.0682]), such that children of women with negative Cognitive Appraisal had higher birthweight, which then predicted higher BMI at age 30 months, compared to children of women with neutral or positive Cognitive Appraisal. For mothers with high social support, Cognitive Appraisal did not have a significant effect on BMI through birthweight (mediation effect 0.0222, CI [-0.1795; 0.2364]). The inclusion of maternal depression and SES in the model did not significantly change these results.

The social support number score did not significantly moderate the effect of Maternal Subjective Stress on BMI at 30 months through birthweight (index -0.0457, CI [-0.1761; 0.0222]). However, social support satisfaction

significantly moderated the effect of Maternal Subjective Stress on BMI at 30 months through birthweight (Fig. 2; index -0.1533, CI [-0.4695; -0.0018]). For mothers with low social support, birthweight significantly mediated the effect of Maternal Subjective Stress on BMI at 30 months, such that greater Maternal Subjective Stress predicted higher BMI at 30 months through higher birthweight (mediation effect 0.6308, CI [0.0033; 1.9053]). However, that mediation effect was not significant for mothers with high social support satisfaction (mediation effect -0.0589, CI [-0.2265; 0.1114]). When maternal depression and SES were included as covariates in this model, the moderated mediation index became marginally significant, likely reflecting loss of statistical power (index 95% CI [-0.4766; 0.0032]; 90% CI [-0.4089; -0.0166]).

Social support satisfaction did not moderate the effect of Cognitive Appraisal of the flood on BMI through birthweight (index 0.0102, CI [-0.1411; 0.1870]).

Social support number did not significantly moderate the effect of objective hardship on BMI through birthweight (index -0.0069, CI [-0.0572, 0.0317]), nor did social support satisfaction (index -0.0645, CI [-0.2386, 0.0383]).

**Table 3** Regression analyses for the moderated mediations models

Predictors	Outcomes					
	Birthweight			BMI at 30 months, child		
	Unstandardized coefficient (SE)	Standardized coefficient	<i>p</i>	Unstandardized coefficient (SE)	Standardized coefficient	<i>p</i>
(a) Cognitive appraisal of the flood consequences by social support number						
Intercept	- 1414.4057 (1266.0626)		0.2668	13.8968 (1.0417)		< 0.0001
Cognitive appraisal of the flood consequences	- 621.1587 (195.5675)	- 0.6764	0.0020	0.0858 (0.2601)	0.0325	0.7422
Birthweight				0.0006 (0.0003)	0.2255	0.0241
Social support number	- 66.315 (30.7406)	- 0.2611	0.0336			
Objective hardship	- 103.6965 (52.5776)	- 0.1902	0.0516			
Previous pregnancies	- 157.8259 (85.6768)	- 0.1655	0.0686			
Age at birth, mother	10.7222 (7.9053)	0.1172	0.1783			
Timing of exposure	0.6292 (0.4761)	0.1151	0.1896			
Sex, child	- 191.8441 (79.9787)	- 0.2089	0.0184			
Gestational age	137.9958 (30.1828)	0.3940	<0.0001			
Cognitive appraisal of the flood consequences × social support number interaction	100.83 (43.3752)	0.5339	0.0223			
(a) Maternal subjective stress by social support satisfaction						
Intercept	- 3344.4913 (1395.6187)		0.018579	13.6184 (0.9952)		< 0.0001
Maternal subjective stress	1373.8072 (683.0776)	1.2050	0.0472	0.6792 (0.3127)	0.2071	0.0322
Birthweight				0.0006 (0.0003)	0.2178	0.0244
Social support satisfaction	194.4871 (106.8011)	0.3154	0.0719			
Objective hardship	- 110.1687 (58.9498)	- 0.2021	0.0648			
Cognitive appraisal of the flood consequences	- 220.8536 (84.5957)	- 0.2405	0.0105			
Previous pregnancies	- 128.6355 (85.2883)	- 0.1349	0.1349			
Age at birth, mother	9.1798 (8.0761)	0.1004	0.2586			
Timing of exposure	0.6593 (0.4931)	0.1206	0.1845			
Sex, child	- 167.1942 (79.3162)	- 0.1821	0.0378			
Gestational age	152.701 (30.2485)	0.4360	< 0.0001			
Maternal subjective stress × social support satisfaction interaction	- 244.6468 (126.231)	- 1.1670	0.0557			

## Discussion

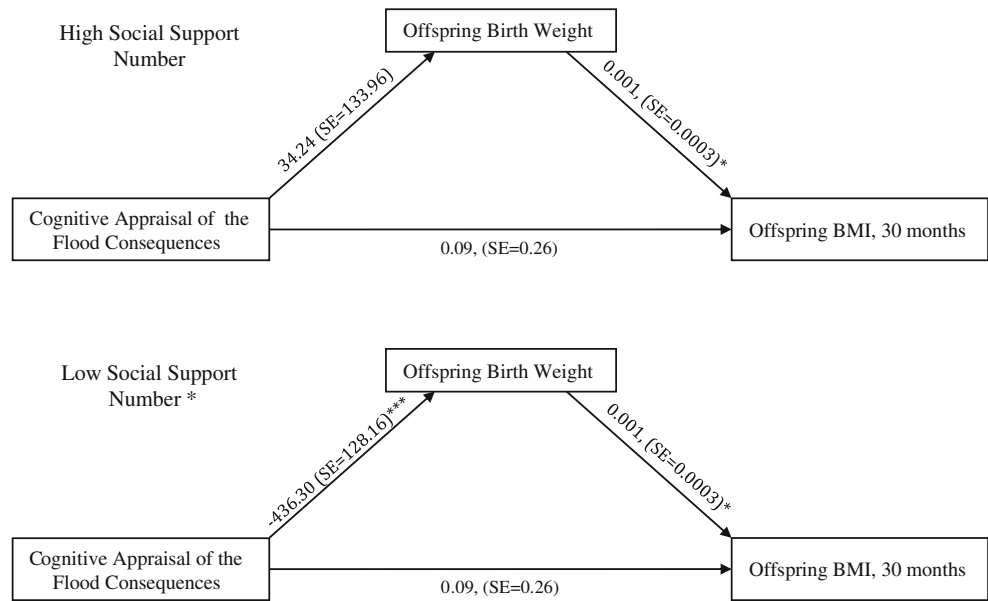
The current study examined effects of PNMS, birthweight, and social support on BMI in early childhood. The effects of PNMS on birth outcomes, specifically for women with less optimal social support, were associated with continued adverse outcomes in early childhood. For women with fewer support providers, a negative appraisal of the consequences of the flood predicted higher childhood BMI through a higher birthweight. This effect was not observed in mothers with a high number of social support providers during pregnancy. Similar effects were observed for social support satisfaction. In mothers who were less satisfied with their social support, birthweight mediated the effect of maternal stress on childhood BMI, such that greater maternal stress predicted higher birthweight, which in turn

predicted higher BMI. In contrast, no association was found between flood stress and birthweight among mothers who reported high social support satisfaction, despite a significant, positive association between flood stress and BMI.

These results suggest that high social support acts as a buffer for maternal stress and negative cognitive appraisal during pregnancy. For mothers who reported low social support, children weighed more at birth and continued to weigh more 2½ years later. However, for mothers with high social support, no such effects were observed. Thus, social support is an important factor for consideration in pregnant mothers because it not only impacts the mothers, but also their children.

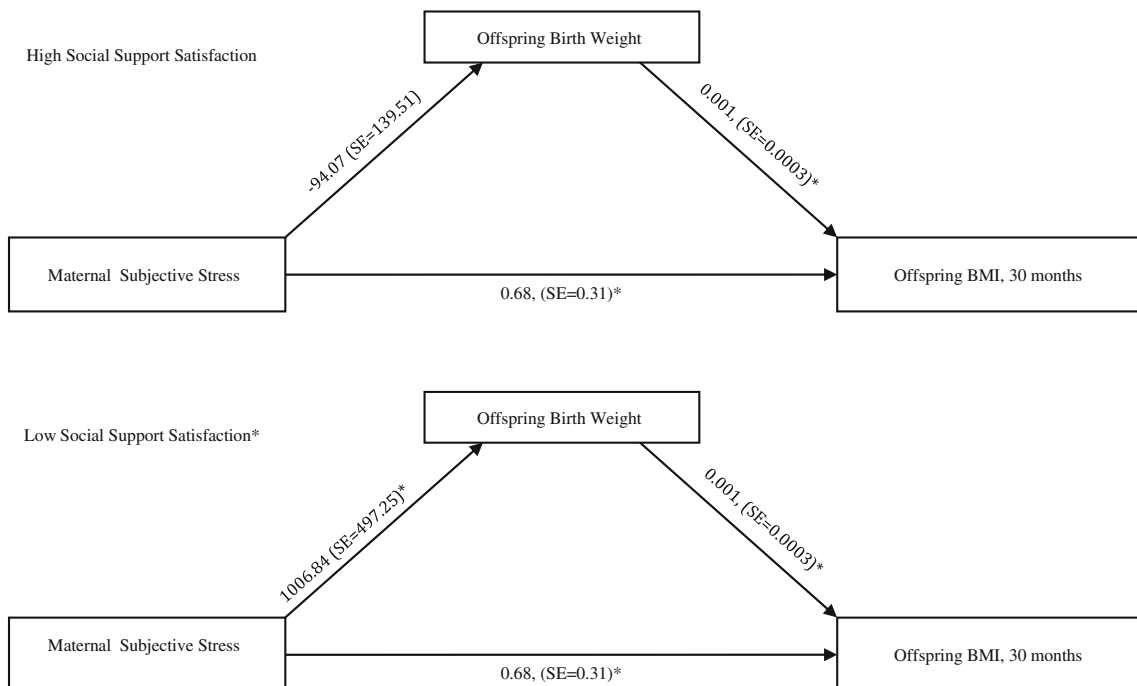
Effects of social support, both direct and indirect, have been observed in other studies of maternal stress. A study of army wives indicated that women with low social support and high life

**Fig. 1** Moderated mediation model depicting interaction between social support number and cognitive appraisal of the flood consequences in predicting offspring birthweight and offspring BMI at 30 months



change as a result of the pregnancy experienced more pregnancy complications than women with high social support (Nuckolls et al. 1972). In addition, Glazier and colleagues (Glazier et al. 2004) found that pregnant women with lower levels of social support were more vulnerable to life stress than women with high social support. The current study adds to the existing literature by measuring the effects of the interaction between PNMS and prenatal social support from birth to age 30 months.

The current findings are consistent with previous research indicating that PNMS has deleterious consequences for the developing fetus that can be observed at birth and in childhood (Lou et al. 1994; Mulder et al. 2002). However, results are contrary to those of several studies that observed lower birthweight among children of mothers experiencing prenatal stress (Bussi eres et al. 2015). Notably, in the current study, the pattern of increased birthweight and later childhood weight



**Fig. 2** Moderated mediation model depicting interaction between social support satisfaction and maternal subjective stress in predicting offspring birthweight and offspring BMI at 30 months. Note: \* $p < .05$ . \*\*\* $p < .001$ .

Objective stress, number of previous pregnancies, mothers' age, days of in-utero exposure to the flood, offspring sex, and gestational age were included as control variables

was only observed among offspring of mothers who reported low social support.

Previous research has indicated that PNMS affects birth outcomes and early childhood outcomes; however, studies examining the buffering effect of social support on offspring outcomes have yielded mixed results. Moreover, although previous research has implicated the intrauterine environment as a potential risk factor for childhood obesity (Gluckman and Hanson 2008; Li et al. 2010), longitudinal research examining this association and potential moderating variables has been limited. Results from our first study of PNMS due to a natural disaster, Project Ice Storm, indicated that prenatal maternal objective stress exposure predicted BMI from age 5 to 15 years, and that the association increased in magnitude with age (Liu et al. 2016). Interestingly, Project Ice Storm found this association with objective exposure but not maternal subjective stress, as found here. Furthermore, although associations between PNMS and childhood obesity have now been replicated in several human studies, methods to intervene or to prevent the effects of PNMS on offspring obesity have not been examined extensively. Our results highlight one modifiable aspect of the maternal environment that could be targeted in prevention or intervention efforts.

There are several limitations of the current work. First, analyses are based on a relatively small sample size, which decreases statistical power. Second, the sample consisted of primarily Caucasian women of relatively high SES, which limits the generalizability of the findings. However, the risk of negative birth outcomes and childhood obesity is likely lower among this sample than in the general population, given this sample's high SES. We might expect to see even stronger associations in a more representative sample. Third, the current study did not include a control group of women who were not exposed to stress because the study was originally designed to examine the impact of social support on pregnant women. Nevertheless, the impact of the flood varied substantially across the sample. Finally, despite the inclusion of several covariates, other unmeasured factors could have impacted the study's findings. Future research should continue to examine the intergenerational impacts of stress to determine causal relations.

The independent nature of the flood is a notable strength of this study. Exposure was unlikely to be stratified based on individual differences. All women in the study experienced the same stressor, and the extent of hardship as a result of the flood varied across the sample. The longitudinal nature of this study is also a strength, following families from the perinatal period into early childhood.

In conclusion, the current study found that high PNMS and negative cognitive appraisal, when paired with low social support, are associated with higher offspring birthweight, which is associated with higher BMI at 30 months of age. This finding is particularly important given the increasing prevalence of childhood obesity. Our results highlight a potential prevention and intervention strategy for mothers who experience

stress during pregnancy. Although the pathways through which PNMS influences birth outcomes are complex, the moderating role of social support suggests that focusing on the development and maintenance of interpersonal relationships during pregnancy may mitigate the effect of PNMS on offspring. Future research should aim to both replicate the current results in a larger sample and examine the potential benefit of social interventions for mothers on families and offspring.

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#### Compliance with ethical standards

**Ethical approval** All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

**Conflict of interest** The authors declare that they have no conflict of interest.

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