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Disaster-related prenatal maternal stress explains increasing amounts of variance in body composition through childhood and adolescence: Project Ice Storm

Guan Ting Liu [a,1], Kelsey N. Dancause [b], Guillaume Elgbeili [a], David P. Laplante [a], Suzanne King [a,c,*]

[a] Schizophrenia and Neurodevelopmental Disorders Research Program, Douglas Institute Research Center, Verdun, Quebec, Canada
[b] Department of Physical Activity Sciences, University of Quebec at Montreal, Montreal, Quebec, Canada
[c] Department of Psychiatry, McGill University, Montreal, Quebec, Canada

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ABSTRACT

Background: The increasing prevalence of childhood obesity worldwide has become a public health issue. While many factors are involved in the development of obesity, stress during pregnancy has been linked to adiposity. However, research involving stressors that are independent of pregnant women's socioeconomic and psychological characteristics is rare. The present study made use of a natural disaster (1998 Quebec ice storm) to determine which aspect of the women's disaster experience (objective hardship, subjective stress, and/or cognitive appraisal) were associated with body mass index levels and/or waist to height ratio across childhood and adolescence.
Methods: Measure of objective hardship, subjective stress, and cognitive appraisal were obtained following the 1998 Quebec ice storm. We measured height, weight, and waist circumference in children at ages 5½, 8½, 11½, 13½, and 15½.
Results: Our results show that higher prenatal maternal stress was associated with higher body mass index levels and central adiposity in children of ages 5½, 8½, 13½, and 15½. The effects of prenatal maternal stress on anthropometric measurements tend to increase as the children grew older.
Discussion: The findings of this study highlight the long-lasting effect of prenatal stress on body composition, and are compatible with the current theory of fetal programming. Hopefully, our increased knowledge of the effects of prenatal stress on the fetus will lead to improved awareness and the creation of early intervention programs, ultimately improving women's and children's health in the future.

1. Introduction

The continuing rise in obesity worldwide has become a pressing public health issue among both children and adults. For instance, a survey in 2009 estimates that 61% of Canadian adults and 26% of Canadian children suffer from either overweight or obesity (Statistics Canada, 2011). The regulation of body composition is complex and multifactorial. The increasingly sedentary lifestyle that developed with the advancement of technology is often cited as the most prominent factor for the modern obesity epidemic (Carroll and Dudfield, 2004; Huizink et al., 2008). Furthermore, a large body of research on the Developmental Origins of Health and Disease (DOHaD) (Barker, 2004; Gluckman et al., 2009) now shows that adverse conditions experienced by the pregnant female, such as inadequate nutrition, alters fetal programming and has lasting effects on the offspring. In the Dutch Hunger Winter study, nutritional restriction as the result of a famine predicted increased incidence of obesity (Ravelli et al., 1976). Prenatal maternal stress (PNMS) might have similar programming effects. Existing studies suggest that higher PNMS predicts increased body mass index (BMI) in children (Dancause et al., 2012), adolescents (Hohwu et al., 2014), and later in life (Schulz, 2010). Another study revealed that young adults whose mothers were exposed to bereavement in pregnancy showed increased risk of overweight and obesity (Hohwu et al., 2014); previously a similar linkage was also found in children aged 12–15 years old (Li et al., 2010).

The current body of PNMS research is limited in several ways.

* Correspondence to: Douglas Institute Research Center, 6875 LaSalle Boulevard, Verdun, Québec H4H 1R3 Canada.
E-mail addresses: guanting.liu@mail.mcgill.ca (G.T. Liu), kelseydancause@gmail.com (K.N. Dancause), Guillaume.Elgbeili@douglas.mcgill.ca (G. Elgbeili), david.laplante@douglas.mcgill.ca (D.P. Laplante), suzanne.king@mcgill.ca (S. King).
[1] Guan Ting Liu is presently at Chicago Medical School, Rosalind Franklin University of Medicine and Science, North Chicago, Illinois, United States.

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Table 1
Sample description.

Age	n	Child's sex		Timing of exposure			
		Males	Females	Preconception	1st trimester	2nd trimester	3rd trimester
5½	111	56	55	24	34	26	27
8½	90	46	44	22	29	22	17
11½	67	35	32	21	16	17	13
13½	66	37	29	16	15	18	17
15½	52	30	22	15	17	13	7

In animal research, rats or non-human primates can be randomly assigned to stressors in a controlled environment, allowing for causal conclusions to be made; this is not possible in human research. However, animal studies cannot tease apart elements of the human stress response including the degree of the mother's exposure, her cognitive appraisal of the event, and her subjective distress levels. In addition, the timing of PNMS exposure in gestation may moderate the effect of PNMS on offspring cortisol levels and the effect of cortisol levels on anthropometric measurements, respectively. Animals go through different pre- and post-natal developmental processes at different stages than do humans, making direct comparisons difficult. Human studies have their own limitations. Most human PNMS studies, usually retrospective, use everyday life event stressors such as job loss and marital discord. These stressors may not be considered "independent stressors" because they are often subject to personal influences, and personal traits may be heritable, creating genetic confounds. Thus, disentangling the objective, subjective, and cognitive aspects of the stressor, and finding the "active ingredient", would be almost impossible in most human PNMS designs. Furthermore, it is often difficult to assess the timing of these events during pregnancy with precision. It would not be ethically, nor logistically, feasible to conduct a human PNMS study in which randomly assigned stress is applied to a large group of women in different stages of their pregnancies. The use of a natural disaster as a stressor circumvents these limitations. Natural disasters are independent, random, can affect a large population, and their timing can be precisely identified.

Project Ice Storm was launched after the devastating 1998 Quebec ice storm to study measures of stress exposure among women who were pregnant during the disaster, and their children's development. Analyses of participant characteristics showed low correlations between severity of the exposure to the ice storm and sociodemographic measures (Laplante et al., 2016), supporting the independent nature of the exposure.

In a previous Project Ice Storm analysis, objective stress was found to predict childhood obesity at age 5½ years (Dancause et al., 2012). However, it is unknown whether the association between PNMS and adiposity varies as the children grow older; which aspect of the maternal stress response predicts body composition in adolescence; and the extent to which that association is moderated by the timing of stress exposure in utero and by sex.

Our goal was to determine how associations between PNMS and adiposity change with age. Specifically, we tested the following hypotheses: (1) PNMS predicts anthropometric measurements (BMI and waist-to-height ratio) at ages 5½, 8½, 11½, 13½, and 15½; (2) the effect of PNMS on anthropometric measurements are moderated by the sex of the child and the timing in utero of the disaster.

2. Materials and method

The ice storm is counted as among the worst natural disasters in Canadian history (Insurance Bureau of Canada, 2012) and left 3 million people without electricity for as long as 6 weeks during the coldest month of the year. In June of the same year, mothers who were pregnant during the ice storm, or who became pregnant in the three months after the storm, were recruited for a study of PNMS and child development. The initial survey isolated objective hardship and subjective distress; the women's cognitive appraisal of the event as positive, neutral, or negative, was also assessed. Periodic mail-in questionnaires and face-to-face assessments have been used to track the development of their children.

2.1. Participants

Following the ice storm, we contacted obstetricians associated with the four major hospitals in the Montérégie, a region southeast of Montreal that endured the longest power losses from the storm. These obstetricians identified patients who were pregnant during, or conceived within 3 months of, the storm and who were at least 18 years old. The first questionnaire, "Reactions to the storm," was mailed on 1 June 1998 to 1440 women. Of 224 respondents, 178 consented to follow-up and were sent a second questionnaire, "Outcomes of the pregnancy," 6 months after their pregnancy due date. Of these, 177 returned the second questionnaire. Level of education was higher for respondents than in the Montérégie in general: 61.0% of respondents had a college degree or higher compared to regional figures of 45.3%, for women aged 20–44 in the 2001 census (http://www12.statcan.ca/english/census01/home/index.cfm).

Body composition data (height and weight), were obtained by a trained research assistant when the children were aged 5½, 8½, 11½, and 15½ years. The sample sizes range from 52 at age 15½ to 111 at 5½; these data were available for at least one age for 123 children. A description of the participants at each age is reported in Table 1 as a function of child sex and period of exposure. Comparisons between families who participated in at least one assessment and those who did not indicated that participating families had higher socio-economic status ($p=0.03$). Significant group differences were not observed for the PNMS measures nor maternal age.

The protocols for each assessment were reviewed and approved by the Research Ethics Board of the Douglas Institute Research Center. Mothers provided informed written consent for each assessment. Youth provided informed written assent from the assessment at age 11½ years onward.

2.2. Outcome measures

Body Mass Index (BMI) was defined as the children's total body mass (kilograms) divided by the square of their body length (meters). Standing height was measured without shoes to the nearest 0.1 cm and weight to the nearest 0.1 kg at each age of assessment. Waist-to-Height Ratio (WHtR), an index of central adiposity, was defined as the children's waist circumference (cm) divided by their height (cm). This measure was obtained at each assessment period starting when the children were 8½ years of