Published in final edited form as:

Sleep Health. 2018 October ; 4(5): 397–404. doi:10.1016/j.sleh.2018.07.013.

Maternal Antenatal Stress Has Little Impact on Child Sleep: Results From a Pre-Birth Cohort in Mexico City

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Abstract

Study Objectives: Maternal antenatal stress may influence offspring development and behavior, but any association with child sleep is unknown.

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Work performed at: Division of Chronic Disease Research Across the Lifecourse, Department of Population Medicine, Harvard Medical School and Harvard Pilgrim Health Care Institute, 401 Park Drive Suite 401E, Boston, MA 02215, which was Dr. Chatterjee's previous affiliation.

Conflict of Interest: The authors have no financial conflicts of interest to disclose.

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Methods: From 2007 to 2011 we recruited pregnant women in Mexico City to the PROGRESS pre-birth cohort. Mothers completed the Perceived Stress Scale (PSS, a 4-item questionnaire assessing past-month stress), the Crisis in Family Systems (CRISYS) measure assessing Negative Life Events (NLEs, how many domains among the 11 assessed in which the mother experienced a stressful event in the prior 6 months)—with higher scores reflecting higher stress—and provided 5 timed salivary samples per day on two consecutive days, from which we derived cortisol area under the curve, slope, and awakening response. At age 4-6 years, children's sleep was estimated using accelerometry over a 7-day period. We performed secondary analysis of associations of antenatal maternal stress with child sleep duration and efficiency (time asleep/time in bed), using linear regression adjusted for maternal and child characteristics.

Results: Among 594 mother-child dyads, mean antenatal PSS score was 5.2 (SD=3.2) out of 16 and mean NLE was 3.2 (SD=2) out of 11; child sleep duration was 7.7 hours (SD=0.7), and sleep efficiency was 79% (SD=6). There was no association between any of the stress measures—PSS, NLE, or salivary cortisol—and sleep duration or sleep efficiency, in adjusted or unadjusted models.

Conclusions: Among mother-child dyads in a Mexico City cohort, antenatal stress was not associated with important changes in child sleep at 4-6 years.

Keywords

sleep; stress; accelerometry; cortisol

Introduction:

Increasing evidence indicates that inadequate sleep is associated with higher risks for adverse health outcomes. Short sleep duration in infancy and childhood are risk factors for subsequent obesity,^{1,2} and there is a suggestion that it is also associated with type 2 diabetes mellitus biomarkers in children.³ In a recent systematic review, short sleep duration was also associated with poorer cognitive performance among 8-12 year olds, worse emotional regulation, and worse quality of life/well-being.⁴ Short sleep duration is not the only sleep measure associated with undesirable health outcomes; low sleep efficiency is also associated with worse school outcomes in school-age children, suggesting that frequent nighttime awakenings may affect cognition.⁵ And unfortunately, recent evidence suggests that children and adolescents are getting less sleep than recommended,^{6,7} with additional evidence that shorter sleep duration early in life persists over the life course.^{8,9} Thus, understanding risk factors for poor sleep in childhood is important.

Maternal smoking during breastfeeding seems to impair infant arousal¹⁰ and decrease infant sleep duration.¹¹ In prospective postnatal studies, maternal depression during childhood may affect child sleep patterns.¹² However, to our knowledge, no prospective studies starting in the antenatal period have examined maternal antenatal risk factors for shorter sleep duration and less efficient sleep in children.

Stress can be assessed based on the environmental demands one experiences (e.g., negative life events), how one appraises a stressor in terms of whether it is threatening and whether

they are able to cope effectively (e.g., perceived stress), as well as biologically (e.g., HPA response).¹³ Cortisol binds to mineralocorticoid receptors in the hippocampus and glucocorticoid receptors elsewhere to regulate sleep and arousal. Both via an increase in cortisol levels and via an up-regulation of cortisol releasing hormone, increased stress leads to greater arousal and less sleep.¹⁴ In numerous cross-sectional studies, higher stress has been associated with less sleep, as well as more fragmented and lower quality sleep.¹⁵ Both stress and short sleep duration are associated with higher cortisol levels in a given individual.¹⁶

A small study in Newark, New Jersey of 21 mother-child pairs demonstrated a cross-sectional relationship between concurrent maternal stress and shorter sleep duration in their preschool-aged children.¹⁷ However, we could not find literature assessing the longitudinal relationship between maternal antenatal stress and subsequent child sleep. Higher maternal cortisol levels have been shown to influence other offspring neurobehavioral outcomes—for example, maternal antenatal stress has been associated with greater risks for attention deficit disorder/hyperactivity and anxiety in childhood,¹⁸ and depression in adolescence.¹⁹ Higher antenatal stress is associated with higher adrenocorticotrophic hormone and cortisol during pregnancy,²⁰ as well as decreased ability of the placenta to metabolize cortisol.²¹ Higher maternal antenatal stress is associated with higher salivary cortisol levels in their 14-15 year old offspring.¹⁹ Because maternal antenatal stress seems to impact the HPA axis in their offspring, and because the HPA axis influences sleep, it is reasonable to hypothesize that maternal antenatal stress may also impair subsequent child sleep.

In the present study, we conducted a secondary data analysis examining the relationship between maternal antenatal stress and child sleep duration and efficiency—the percentage of in-bed time a child spends asleep—in a cohort of mothers and children in Mexico City. We hypothesized that higher maternal antenatal stress would be associated with shorter duration of child sleep and lower child sleep efficiency in this cohort.

Methods:

Population/Setting:

From 2007 to 2011, we recruited 1054 pregnant women in the early 2nd trimester into the Programming Research in Obesity, Growth, Environment and Social Stressors (PROGRESS) cohort. All women were receiving prenatal care at clinics belonging to the Mexican Social Security System in Mexico City. Exclusion criteria included multiple fetuses (e.g. twins); consumption of one or more alcoholic beverages per day; history of heart or kidney disease or seizure disorder requiring daily medications; use of corticosteroids; any other medical conditions that could cause low birth weight; and logistic reasons that would interfere with data collection, such as living in a household outside the metropolitan area. After birth, we further excluded infants with an Apgar score at 5 minutes of 6 or less, a condition requiring treatment in neonatal intensive care unit, or serious birth defects. We excluded children with severe prematurity (<32 weeks) from this analysis. The recruitment process has been described in detail elsewhere.^{22,23} Research ethics committees of the participating institutions approved the study.

Procedures:

Study staff explained the study to the participants and obtained written informed consent. During the mother's initial study visit during pregnancy (2nd trimester), we collected information on health status and on social and demographic characteristics. Research staff collected information on newborn characteristics from the hospital delivery record. After delivery, each mother-infant pair visited the research center at the National Institute of Perinatology in Mexico City for evaluation at a series of study visits, conducted every 6 months until 24 months and at 4-6 years of age. In the present analysis we included the 609 mother-child dyads who had completed the 4-6 year visit as of April 2016. We included data collected from mothers at the prenatal visit; data collected from birth records about the newborn infants; and data collected from mothers and children at the 4-6 year visit.

Antenatal Stress measures:

The exposure in this study was maternal antenatal stress, which we assessed based on self-reported measures of environmental demands (negative life events) and stress appraisal (perceived stress), as well as a biological measure of HPA functioning (salivary cortisol). During the initial visit, a psychologist conducted a face-to-face interview with mothers assessing global stress appraisal with the 4-item Perceived Stress Scale (PSS).²⁴ The PSS consists of four general questions about stress (e.g., "In the last month, how often have you felt that you were unable to control the important things in your life?") with four response choices reflecting frequency ("0=never, 1=almost never, 2=sometimes, 3=fairly often, 4=very often"), resulting in a cumulative score from 0-16. A higher score indicates higher level of stress. The PSS demonstrates good internal consistency, test-retest reliability, and factorial validity,²⁵ and has been validated in a Spanish-speaking population in Mexico.²⁶ During the same interview we assessed negative life events experienced in the past 6 months with the original 64-item Crisis in Family Systems scale.²⁷ The 64-item CRISYS asks about stressful life events in 11 domains (financial, legal, career, relationships, medical pertaining to respondent and to others, safety in the community and at home, other home issues, difficulty with authority, and discrimination) over the previous 6 months, with several items asked in each domain. For example, in the Financial domain, participants were asked "Did you go without food because you did not have the money to pay for it?" and in the Relationships domain, "Did you get a divorce or break up with a partner?" Because research demonstrates increased vulnerability when experiencing events across multiple life domains,²⁸ we summed the number of domains in which mothers reported at least one negative life event to get a Negative Life Events (NLE) domain count from 0-11, with higher scores indicating stress in more domains, as has been done in prior research.²⁹ Because stressful events were assessed over the previous 6 months, some of these events may have occurred prior to pregnancy, but we hypothesize that the ongoing stress from the types of events assessed by the NLE survey would persist into the antenatal period.

In addition, during pregnancy mothers provided timed salivary samples, from which we measured cortisol. We provided women with verbal and written instruction to provide samples in Salicaps containers (IBL International, Hamburg, Germany) using the passive drool technique at five specified times on each of two consecutive days (weekdays or weekends): upon awakening, 45 minutes after waking, 4 hours after waking, 10 hours after

waking, and at bedtime. We instructed the women not to eat, brush their teeth, or drink liquids for at least 15 minutes before providing the sample and not to drink caffeinated beverages before collecting the first two samples. After sample collection, women recorded the collection time on the tube and in a diary, and refrigerated samples until pickup, after which we stored them at -70°C until shipment on dry ice to Dresden, Germany for analysis. We used a chemiluminescence assay with sensitivity of ~ 0.16 ng/ml (IBL; Hamburg, Germany) to assay salivary cortisol.²²

From these samples we derived three measures of maternal antenatal HPA axis activity. These three commonly used indicators quantify three different aspects of the diurnal cortisol pattern, which may be differentially associated with health outcomes.

Cortisol Awakening Response: The difference between the wake-up sample and the sample collected 45 minutes later (after transforming both to logarithms; equivalent to the log of ratio of the two samples).

Area Under the Curve (AUC): Calculated using log-transformed values and adjusting (residual from regression equation) for total waking time.

Diurnal slope: Calculated by separately fitting a linear regression line for each participant predicting the log-transformed biomarker values from time (hours since awakening) and treating the slope and intercept as random coefficients (latent variables) in a multilevel, repeated measures model. To avoid effects of the morning rise on diurnal slope, the second sample (wake-up + 45 min) was excluded from estimation of slopes. Each measure was calculated by day and then averaged across the two days of collection.²²

Cortisol follows a circadian cycle, reaching its lowest levels in the early evening, rising in the second half of the overnight period, and having a steep rise within the 45 minutes after a person wakes up and declining throughout the day. CAR, AUC, and slope may be variably associated with stress and health outcomes so researchers typically examine associations across all summary variables as we did here. Overall, flatter cortisol curves (i.e. CAR and slope that are closer to zero) and higher levels of cortisol (AUC as a measure of total diurnal cortisol) could indicate chronic stress.²²

Sleep outcomes:

We assessed child sleep outcomes—child sleep duration and sleep quality—using data from ActiGraph GT3x+ accelerometers (ActiGraph, Pensacola, FL) worn by the child on their non-dominant wrist over a 7-day period. The ActiGraph measured motion in oscillations as well as ambient light. Similar accelerometer protocols have been validated against polysomnography in children.^{30–32} To keep the children from tampering with or removing the accelerometers, we used plastic hospital-style ID bracelets instead of Velcro wrist-straps. The parents were given additional bracelets in case the accelerometer had to be taken off and put back on during the observation period (e.g., the child reported that the bracelet was too tight). Children began wearing the accelerometers during their initial study visits, and a study staffer picked up the accelerometer after the child had worn it for 1 week.

To calculate an estimate of sleep duration, we identified sustained periods with low to no physical activity (defined as <1000 oscillations per minute). Using accelerometry software ActiLife v6.11.9, we used the Sadeh sleep algorithm to estimate the number of minutes the child slept within each sleep period.³³ The “time in bed” variable was produced by manually scoring the accelerometer data, based on a standardized protocol we developed with input from the sleep laboratory at Brigham and Women’s Hospital. We used reductions and increases in the number of counts of physical activity measured in each 60-second epoch to bookend when the child lay down at night and got up in the morning. We used the first 60-second epoch with <1000 counts of physical activity as the start of a “time in bed” period, and the last epoch with <1000 counts as the end of that period. We then calculated child sleep efficiency (% of in bed time spent asleep) by dividing time asleep (as determined by accelerometry) by the total time in bed. This approach with the Actigraph GT3x has been validated previously against polysomnography to assess sleep duration and efficiency in adults.³⁴ In addition to estimating total 24-hour sleep duration and sleep efficiency, we calculated nighttime sleep and sleep efficiency by identifying the longest sleep period consistent with nighttime.

While we asked the children’s parents to complete sleep diaries during the week their children wore the accelerometers, not all parents did so. The sleep diaries were retroactive, meaning that parents were asked to report the times that their children went to bed, tried to sleep, and went to sleep on the previous night. Parents also complained that they had no way of knowing when their child tried to sleep, fell asleep, or woke up, only what time they were put to bed. The sleep diaries we did receive often disagreed with the accelerometry data, particularly with regards to naptimes; the data frequently showed a high level of prolonged physical activity at times that the sleep diary reported sleep. Because of these problems, we opted to rely primarily on the accelerometry data as an objective measure of sleep, and to refer to the sleep diaries only when necessary to clarify suspected naptimes (e.g., whether quiet periods in the afternoon were valid naptimes or simply periods of low physical activity).

Covariates:

Antenatal maternal covariates we collected at the initial prenatal study visits included age, height, and weight, from which we calculated body mass index (BMI). Trained study staff measured height and weight of mothers (clothes off except for underwear, no shoes) with the Health-O-Meter combined scale and stadiometer (Scaleomatics Inc., Cleveland, OH), measuring weight to the nearest 100 grams and height to the nearest 0.5cm.

We assessed family socioeconomic status (SES) with a questionnaire commonly used in social science research in Mexico that assigns a level from 1 to 6 based on thirteen questions about housing quality, sanitary infrastructure, appliances, communication and entertainment technology, educational attainment of the head of household, and expenses.³⁵ A family in the highest category (6) typically lives in a house of 8 rooms or more, has on average 2 cars, and adults have a college degree or further post-graduate education. Families in the bottom SES levels typically live in dwellings with 3 rooms or less, do not own a car (though 2 out of 5 might own a phone), and adults in these households have typically stopped their education

after primary school. For this analysis we collapsed the 6 categories into 3 because of small numbers in certain categories. From the delivery record, investigators assessed child gestational age, sex, birth weight and length.

At the 4-6 year visit, trained research staff measured child height and weight, with children wearing only underwear, in duplicate, using the Health-O-Meter (Scaleomatics Inc., Cleveland, OH). From these data we calculated BMI and BMI z-scores using World Health Organization norms.³⁶ Also during the 4-6 year visit, trained study staff used the InBody device (InBody USA, Cerritos, CA) to measure maternal weight to the nearest 100 grams (mothers wore only underwear and no shoes) and a stadiometer to measure maternal height to the nearest 0.1cm. We also assessed maternal antenatal smoking status, asking both about current and lifetime smoking.

Of the original 1054 recruited participants, 760 reported for at least 1 visit between 6 and 24 months and 609 presented to the 4-6 year visit as of April, 2016. We included 594 mother-child dyads with accelerometry data in this analysis. Compliance with accelerometry was high; 96.8% of children wore the Actigraph for at least 6 nights.

Data Analysis:

We determined mean (SD) or distribution of each of the maternal and child characteristics. To get an initial sense of the nature and relationship between variables, we examined simple associations between maternal/child characteristics and low and high stress (PSS score divided at the median of 5), and between these characteristics and sleep duration divided into quartiles of sleep duration. We examined differences in maternal and child characteristics according to quartiles of sleep duration using ANOVA (continuous variables) or Fisher's Exact (categorical variables). We calculated Pearson correlation coefficients between each pair of the maternal antenatal stress measures (PSS score, negative life events subscale score, cortisol area under the curve, cortisol slope, and cortisol awakening response). We used linear regression to model the relationship of each measure of maternal antenatal stress with nighttime sleep duration and efficiency. After unadjusted analysis, we examined relationships adjusted for child sex and age at outcome. In a third model, we additionally adjusted for maternal age, prenatal BMI, and SES. In a fourth model, we additionally adjusted for maternal report of ever having smoked. In a final model we adjusted for gestational age and birth weight, potential intermediates. For regression models we included mother-child dyads with all covariates present, resulting in sample sizes ranging from 541 to 553 depending on the exposure/outcome combination. We used Statistical Analytic System (SAS) software, version 9.4, for all data analysis.

Results:

Of those included in this analysis, mean maternal age at recruitment was 27.6 (SD=5.6) years, 305 (51%) were in the lowest SES category, and 244 (60%) reported ever having smoked. PSS score was 5.2 (SD=3.2) out of a possible 16 points, and mean NLE domain count was 3.2 (SD=2) out of a possible 11 domains. Time-weighted average cortisol area under the curve was 9.4 (SD=3.1) nmol-min/L, slope was -1.02 (0.44) nmol/min/L and

awakening response was -0.04 ($SD=8.7$) nmol/min/L (Table 1). There was no difference in cortisol measurements from weekend day samples compared to weekday samples.

At birth, mean gestational age was 38.3 ($SD=1.7$) weeks and 302 (51%) of the children were male. Among children at the 4-6 year visit, mean age was 57.4 ($SD=6.3$) months (i.e. 4 years and 9.4 months), and mean BMI z-score was 0.21 ($SD=1.1$) units. Children averaged 9.6 ($SD=0.7$) hours in bed, 7.7 ($SD=0.7$) hours of sleep per 24-hour period, and 7.7 ($SD=0.7$) hours of nighttime sleep duration and had an average sleep efficiency (time asleep/time in bed) of 80.6% ($SD=6.1$) (Table 1).

There was moderate correlation between PSS and NLE and moderate correlation between the salivary cortisol measures, but no correlation between either of the survey stress measures and any of the cortisol measures (Table 2).

Among the 232 mothers who reported a PSS score of 6 or higher, 58% were in the low SES group, while in the 362 mothers who reported PSS score 5 or less, 51% were in the low SES group. Mothers in the higher stress group were more likely to have ever smoked a cigarette (66%) than those in the lower stress group (60%), but rates of current smoking and reported exposure to violence were similar between high and low PSS score groups, as were child characteristics (Table 3).

Children in the lowest sleep quartile slept an average of 6.8 ($SD=0.4$) hours, while children in the highest quartile slept 8.6 ($SD=0.4$) hours during a 24-hour period (Table 4). Children in the highest sleep quartile group were more likely to have families in the low SES group (59%), compared to 52%, 48%, and 46% in the third, second and lowest quartiles of sleep, respectively. At the 4-6 year visit, the mothers of children in the lowest sleep quartile had an average BMI of 28.3 ($SD=5.2$), compared to the mothers of children in the highest sleep quartile (26.5 ($SD=4.6$)). Similarly, children in the lowest sleep quartile had a mean BMI z-score of 0.4 ($SD=1.2$), while children in the highest sleep quartile had an average BMI z-score of 0.03 ($SD=0.8$). Other maternal and child characteristics and stress measures were similar across sleep quartiles (Table 4).

In this analysis, our multivariable models revealed no association of antenatal maternal perceived stress, experience of negative life events in the past 6-months, or maternal cortisol with child sleep duration (Table 5). We repeated analyses using 24-hour total sleep, rather than just nighttime sleep, in order to include naps as well as with weekday and weekend sleep, since work and school schedules might change when and how much sleep parents and children get. In all cases, our findings were similar (data not shown).

Our multivariable models also revealed no association of antenatal maternal perceived stress, experience of negative life events in the past 6-months, or maternal cortisol with child sleep efficiency (Table 6).

Discussion:

In a pre-birth cohort in Mexico we longitudinally examined the relationship between maternal antenatal stress and subsequent sleep in offspring. Maternal antenatal stress was not associated with child sleep duration or sleep efficiency.

Mean child sleep duration in this cohort of 4-6 year old children was 7.8 hours (95% CI 6.3-9.2), well below the recommended duration of 10-13 hours that the American Academy of Sleep Medicine put forth and the American Academy of Pediatrics endorsed.³⁷ This is especially concerning given that we used accelerometry rather than parent reports of child sleep as our measure. Indeed, in our study, children spent roughly two hours in bed by parent report when they were not asleep, as measured by accelerometry, supporting the literature that parent report of time in bed may not be a good measure of actual sleep time.³⁸

As described above, a growing body of evidence links shorter sleep duration in childhood with worse school performance,⁴ undesirable health outcomes such as obesity,^{1,2} and perhaps even lifetime mortality risk.³⁹ Consistent with our findings, recent study of 229 Mexican-American children aged 8-10 found that a majority were short sleepers, receiving less than the 10 hours of sleep recommended by the National Sleep Foundation.⁶ Our knowledge of what leads to shorter sleep duration in childhood is limited, though socioeconomic status,⁴⁰ parental and family factors,⁴¹ screen time,⁴² and lack of physical activity⁴³ likely contribute.

Contrary to what we expected, children from families with lower SES had higher sleep duration. It is possible that the relationship between SES and sleep is different in higher income countries (where previous studies have been done) than in low- and middle-income countries. For example, the presence of appliances and entertainment technology were part of the measure of SES for our cohort in Mexico City, such that higher SES might have meant more exposure to nighttime electric light, noise, and screen time that children in lower SES groups were not exposed to. Part of the difficulty in increasing child and adolescent sleep duration may be our lack of understanding of some additional factors that contribute to shorter sleep duration. Prior studies looking at causes have been cross-sectional, or prospective starting in childhood. Our study is unique in that it looks prospectively at potential risk factors for short sleep duration and less efficient sleep, such as maternal stress, in the antenatal period.

We utilized two different subjective measures of stress that have been previously used in the literature. The PSS measures stress over the past month, while the NLE subscale of the CRISYS instrument measures stressful events over the previous 6 months over a wide range of domains. The CRISYS scale asks about career, financial, relationship, and legal stressors, violence, and prejudice²⁷, covering a broad set of domains that fall under the umbrella of social determinants of health. The mean NLE in our cohort was 3.2 (2.0), slightly higher than the mean NLE of 1.85 (1.82) in the Asthma Coalition on Community, Environment, and Social Stress cohort, a cohort of 500 women and their children in Boston, Massachusetts.²⁸ Thus, we believe that the PSS and NLE were reasonable tools for assessing maternal antenatal stress in our cohort. NLE but not PSS had an (albeit small) association

with child sleep. It could be that in this particular cohort in a developing country, the broader, longer-term assessment of social stressors—the NLE—was a more relevant measure of stress.

While our data did not find an association between maternal stress—as assessed by survey measures or by cortisol measures—and poor child sleep, whether because of limitations in our measures of stress, sleep and confounders, or because there is no relationship, stress is still an important factor in human health. Therefore, ongoing efforts to understand contributors to insufficient sleep duration and poor sleep quality, including stress, will be valuable.

Strengths of the study include the large sample of women and their children—609 dyads—followed prospectively from mid-pregnancy through more than 4 years postpartum. Additionally, we used several measures of maternal antenatal stress, including three different assessments of maternal cortisol, the PSS score, and the NLE scale. We also used a robust measure of child sleep, wrist-worn accelerometry as opposed to parental report, and collected sleep information for a week. Finally, we were able to collect and adjust for many relevant maternal and child covariates, including socioeconomic status, child characteristics at birth.

An important limitation of this study is the complexity of measuring stress and its physiologic responses. We found it reasonable to think that cortisol and the HPA axis is the pathway by which maternal stress would affect the fetus, as discussed above. It is possible, however, that maternal stress affects the developing fetus via different mechanisms, such as via catecholamines, a manifestation of stress that we did not measure. Also, stress is dynamic over time, but we assessed stress at only one time point during pregnancy. In particular, it is known that maternal cortisol levels vary during pregnancy and around conception⁴⁴ so it is possible that a two-day measure of cortisol was not sufficient to get a true assessment of cortisol levels in mothers. Also, while we had multiple different measures of maternal stress, in the case of cortisol measures and the survey instruments, the measures did not correlate with each other. Furthermore, levels of maternal stress by any of the measures were relatively low, so our findings may not be generalizable to mothers with very high levels of stress. In a cohort with higher levels of stress, the effect on child sleep might have been different.

While hip-worn and similar wrist-worn actigraphy devices have been validated against polysomnography to measure child sleep, the ActiGraph GTX3+ itself has not been. We recognize this as a limitation, although we thought that the benefits in terms of adherence would outweigh this limitation. Another important limitation was that there were key confounders we did not measure, for example, how many people the child shared a sleeping space with, or the presence of electronic devices such as telephones, televisions, and tablet devices. Furthermore, not all dyads followed up for all measures, and we only included complete cases in our analysis, leading to lower power for certain models. Our loss to follow up, however, is similar to that in other birth cohorts, and it has been shown that bias from nonparticipation is low.⁴⁵ Also, in our dataset mothers of children who had accelerometry data were very similar to those who did not on important measures such as age, BMI, SES,

stress and sleep measures (data not shown). Another limitation in our study was the use of accelerometry for sleep measurement. We chose accelerometry rather than parental report of sleep because of its greater objectivity, and rather than polysomnography because of its greater practicality, though concerns about the specificity of accelerometry for pediatric sleep assessment remain.^{34,32}

Our study adds to the larger body of literature on the effects of psychosocial stressors on sleep and other health outcomes, raising questions about whether and how stress during their mothers' pregnancy may lead to long-term negative effects on children. Additional work clarifying the mechanisms by which antenatal maternal stress affects child psychosocial health is needed. Pregnancy is a particularly vulnerable time for stress, which can impact both mother and child, and work evaluating interventions to decrease or moderate the effects of antenatal maternal stress will be important. Indeed, given the broad health impacts of stress additional investigators and community organizations are looking at interventions to decrease stress and its health effects.⁴⁶

Acknowledgments

Acknowledgements/Funding: The PROGRESS study was funded by the National Institutes of Health (R01 ES21357). This study was also supported and partially funded by the National Institute of Public Health/Ministry of Health of Mexico. Dr. Chatterjee received funding support from an Institutional National Research Service Award, (T32HP12706), the Ryoichi Sasakawa Fellowship Fund, and the Department of Population Medicine at Harvard Medical School/Harvard Pilgrim Health Care Institute. Dr. Oken was funded by the National Institutes of Health (K24 HD069408, P30 DK092924). The funding sources had no role in study design, data collection or analysis, or in the writing of the manuscript or decision to submit for publication. We would also like to acknowledge the Instituto Nacional de Salud Pública and the American British Cowdray Medical Center for their support providing the research facilities.

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Table 1:

Characteristics of the 594 mother and child dyads in the PROGRESS (Programming Research in Obesity, Growth, Environment and Social Stressors) study who have completed the 4-6 year visit with accelerometry.

	Mean (SD) or n (%)	N
Mothers At Recruitment or 2nd/3rd Trimester Visit		
Age (years) (2 nd Trimester)	27.6 (5.6)	594
Height (cm) (2 nd Trimester)	155 (5)	594
Body Mass Index (kg/m ²) (2 nd Trimester)	26.9 (4.2)	594
Perceived Stress Scale (0-16) (prenatal)	5.2 (2.8)	548
Negative Life Events (NLE), i.e., number of domains of the Crisis in Family Systems Scale in which participants reported a negative event (0-11)	3.2 (2)	549
Cortisol—time-weighted average Area Under the Curve (AUC) (nmol-min/L)	9.4 (3.1)	560
Cortisol—average slope (nmol/min/L)	-1.02 (0.44)	560
Cortisol – Average Cortisol Awakening Response (CAR) (new)	-0.05 (8.07)	560
Socioeconomic Status		594
Low	305 (51%)	
Medium	228 (38%)	
High	61 (10%)	
Mothers at the Child's 4-6 Year Visit		
BMI (kg/m ²)	27.2 (4.9)	556
Perceived Stress Scale (PSS) Score	5.3 (3.1)	546
Ever smoked a cigarette	367 (62%)	587
Current smoker	162 (28%)	587
Children At Birth		
Gestational Age (weeks)	38.3 (1.7)	594
Birthweight (kg)	3.06 (0.43)	594
Sex		594
Male	302 (51%)	
Female	292 (49%)	
Children At the 4-6 Year Visit		
Child Age at the 4-6 Year Visit (months)	57.4 (6.3)	594
Child BMI Z-score at 4-6 Year visit	0.21 (1.1)	594
Number of nights of sleep recorded		594
5 or fewer	19 (3%)	
6	30 (5%)	
7	545 (92%)	
Hours in bed per 24 hours	9.6 (0.7)	594
Hours of sleep per 24 hours	7.7 (0.7)	594
Sleep efficiency, amount of time asleep, as measured	80.6 (6.1)	594

	Mean (SD) or n (%)	N
by accelerometry, divided by the amount of time spent in bed (%)		

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Table 2:

Correlations between prenatal maternal stress survey results and prenatal salivary cortisol measures in 594 children in the PROGRESS (Programming Research in Obesity, Growth, Environment and Social Stressors) study

	Pearson Correlation Coefficients P-values					
	N	Perceived Stress Scale	Negative Life Events	Area Under the Curve (nmol/min/L)	Slope (nmol/L/min)	Cortisol Awakening Response (nmol/L)
PSS: Perceived Stress Scale (0-16)	548	1.00				
NLE: Negative Life Events, number of domains of the Crisis in Family Systems Scale in which participants reported a negative event (0-11)	548	0.32 <0.0001	1.00			
AUC: Area Under the Curve (nmol-min/L)	560	−0.01 0.80	0.001 0.99	1.00		
Slope (nmol/L/min)	560	0.06 0.18	0.04 0.38	−0.29 <0.0001	1.00	
CAR: Cortisol Awakening Response (nmol/L)	560	−0.02 0.60	.004 0.93	0.35 <0.0001	−0.10 0.01	1.00

Table 3:

Characteristics of 548 mothers and children in the PROGRESS (Programming Research in Obesity, Growth, Environment and Social Stressors) study, by low or high stress, as measured by the Perceived Stress Scale (PSS) score, divided at the median score of 5

	Mean (SD) or n(%)	Low Stress (PSS 0-5) n=362	High Stress (PSS >5) n=232
Mothers			
Socioeconomic Status Score			
Low	305 (51%)	171 (47%)	134 (58%)
Medium	228 (38%)	149 (41%)	79 (34%)
High	61 (10%)	42 (12%)	19 (8%)
Maternal smoking behavior (4-6 year visit)			
Never smoked	220 (37%)	143 (40%)	77 (34%)
Former smoker	205 (35%)	127 (35%)	78 (34%)
Current smoker	162 (28%)	90 (25%)	72 (32%)
Children at Birth			
Gestational Age (weeks)	38.3 (1.6)	38.3 (1.7)	38.4 (1.7)
Sex			
Male	302 (51%)	182 (50%)	120 (52%)
Female	292 (49%)	180 (50%)	112 (48%)
Children at the 4-6 Year Visit			
Age (months)	57.4 (6.3)	57.5 (6.3)	57.4 (6.5)
BMI Z-score	0.21 (1.1)	0.22 (1.1)	0.21 (1.1)
Hours of sleep per 24 hours	7.7 (0.7)	7.7 (0.7)	7.7 (0.7)
Sleep Efficiency (%)	81 (6.1)	80.5 (5.9)	80.9 (6.3)

Table 4:

Characteristics of 594 mothers and children in the PROGRESS (Programming Research in Obesity, Growth, Environment and Social Stressors) study, by quartile of child sleep during a 24-hour period

Maternal Characteristics		Least Sleep Quartile (n=148)	2nd Sleep Quartile (n=149)	3rd Sleep Quartile (n=149)	Most Sleep Quartile (n=148)	
Mothers At Recruitment or 2nd/3rd Trimester Visit		Mean (SD) or n (%)				P-value for test of difference
Socioeconomic Status Score						0.45
	Low	68 (46%)	72 (48%)	78 (52%)	87 (59%)	
	Top	62 (42%)	61 (41%)	56 (38%)	49 (33%)	
	High	18 (12%)	16 (11%)	15 (10%)	12 (8%)	
Perceived Stress Scale (016)		5.5 (2.9)	5.0 (2.8)	5.0 (2.8)	5.3 (2.7)	
NLE * (0-11)		3.2 (2.1)	3.3 (2.1)	3.2 (2.1)	2.9 (1.9)	
Cortisol—time-weighted average AUC (nmol-min/L)		9.5 (3.2)	9.0 (3.1)	9.0 (3.1)	9.3 (3.1)	
Cortisol—average slope (nmol/L/min)		−1.05 (0.4)	−0.98 (0.5)	−0.98 (0.5)	−1.02 (0.5)	
Cortisol—average CAR (nmol/L)		0.5 (7.9)	−0.7 (7.9)	−0.7 (7.9)	−0.3 (8.3)	
Age (years)		28.1 (5.5)	28.5 (5.6)	26.9 (5.4)	27.0 (5.8)	0.02
Height (cm)		1.55 (0.06)	1.55 (0.06)	1.56 (0.05)	1.55 (0.05)	0.92
Body Mass Index (BMI) (kg/m2)		27.4 (4.0)	27.5 (4.3)	26.3 (4.1)	26.4 (4.1)	0.004
Mothers at the Child's 4-6 Year Visit						
Maternal BMI (kg/m2)		28.3 (5.2)	27.6 (4.7)	26.6 (4.7)	26.5 (4.6)	0.001
Maternal smoking behavior (4-6 year visit)		51 (35%)	54	61	54	0.42
	Never smoked	50 (34%)	(37%)	(41%)	(37%)	
	Former smoker	44 (30%)	60 (41%)	49 (33%)	46 (31%)	
	Current smoker		33 (22%)	38 (26%)	47 (32%)	
Maternal Perceived Stress Scale (0-16)		5.7 (3.0)	4.9 (3.2)	5.3 (3.2)	5.2 (2.9)	0.25
Children At Birth						
Gestational Age (weeks)		38.3 (1.7)	38.4 (1.6)	38.3 (1.6)	38.3 (1.9)	0.88
Sex						
	Male	76 (51%)	80 (54%)	82 (55%)	65 (44%)	
	Female	72 (49%)	69 (46%)	67 (45%)	83 (56%)	
Children At the 4-6 Year Visit						
Age (months)		57.8 (6.5)	58.1 (6.5)	56.8 (5.8)	57.0 (6.4)	0.12
BMI Z-score		0.4 (1.2)	0.2 (1.2)	0.2 (1.0)	0.03 (0.8)	0.01
Hours in bed per 24 hours		9.1 (0.8)	9.5 (0.6)	9.7 (0.5)	10.3 (0.5)	
Hours of sleep per 24 hours		6.8 (0.4)	7.5 (0.1)	8.0 (0.1)	8.6 (0.4)	
Sleep Efficiency (%)		75 (6)	80 (5)	82 (4)	84 (5)	

* NLE (Negative Life Events): number of domains of the Crisis in Family Systems Scale in which participants reported a negative even

Table 5:

Relationship between maternal antenatal stress measures and sleep duration in mother-child dyads in the PROGRESS (Programming Research in Obesity, Growth, Environment and Social Stressors) study.

Maternal Stress Measure	N	SD	Model 1 ^a	Model 2 ^b	Model 3 ^c	Model 4 ^d	Model 5 ^e
			Effect estimate (95% CI) The coefficient can be interpreted as the change in sleep duration in minutes per standard deviation change in the predictor variable				
Survey Measures							
Perceived Stress Scale (0-16)	541	2.81	-0.02 (-0.48, 0.45)	-0.02 (-0.48, 0.45)	-0.09 (-0.56, 0.38)	-0.04 (-0.52, 0.43)	-0.05 (-0.52, 0.43)
NLE (0-11): Negative Life Events, number of domains of the Crisis in Family Systems Scale in which participants reported a negative event	542	2.02	-0.53 (-1.43, 0.37)	-0.55 (-1.45, 0.36)	-0.50 (-1.41, 0.40)	-0.49 (-1.40, 0.42)	-0.50 (-1.51, 0.42)
Salivary Cortisol							
AUC (nmol/L): time-weighted average Area Under the Curve	553	3.14	0.07 (-0.30, 0.44)	0.06 (-0.31, 0.43)	0.03 (-0.34, 0.40)	0.003 (-0.37, 0.37)	-0.003 (-0.37, 0.37)
Slope (nmol/L/min)	553	0.44	1.39 (-17.16, 19.95)	0.80 (-17.77, 19.36)	-0.25 (-18.80, 18.30)	0.07 (-18.61, 18.75)	0.04 (-18.65, 18.77)
CAR (nmol/L): Cortisol Awakening Response	553	8.07	-0.03 (-0.09, 0.03)	-0.03 (-0.09, 0.02)	-0.03 (-0.08, 0.03)	-0.02 (-0.07, 0.03)	-0.02 (-0.08, 0.03)

^a Unadjusted

^b Adjusted for child age at outcome and sex

^c Additionally adjusted for maternal age, maternal prenatal BMI, and SES

^d Additionally adjusted for mother ever having smoked

^e Additionally adjusted for birthweight and gestational age

Table 6:

Relationship between maternal antenatal stress measures and sleep efficiency in children in the PROGRESS (Programming Research in Obesity, Growth, Environment and Social Stressors) study.

Maternal Stress Measure	N	SD	Model 1 ^a	Model 2 ^b	Model 3 ^c	Model 4 ^d	Model 5 ^e
			Effect estimate (95% CI) The coefficient can be interpreted as the change in sleep efficiency % [(time asleep/time in bed)*100] per standard deviation change in the predictor variable				
Survey Measures							
Perceived Stress Scale (0-16)	541	2.81	-0.11 (-6.40, 6.40)	-0.11 (-6.40, 6.40)	-1.78 (-7.12, 6.05)	-0.71 (-7.12, 6.05)	-0.71 (-7.12, 5.69)
NLE (0-11): Negative Life Events, number of domains of the Crisis in Family Systems Scale in which participant reported a negative event	542	2.02	9.90 (-2.47, 22.28)	9.90 (-2.47, 22.77)	10.40 (-1.98, 22.77)	10.40 (-1.98, 23.27)	10.40 (-1.98, 23.27)
Salivary Cortisol							
AUC (nmol/L): time-weighted average Area Under the Curve	553	3.14	1.27 (-3.82, 6.37)	0.95 (-4.14, 6.37)	0.64 (-4.45, 6.05)	0.64 (-4.46, 6.05)	0.64 (-4.46, 5.73)
Slope (nmol/L/min)	553	0.44	-6.82 (-32.20, 19.77)	-6.14 (-32.05, 19.77)	-6.59 (-32.73, 19.09)	-6.82 (-32.50, 19.32)	-6.82 (-32.27, 19.77)
CAR (nmol/L): Cortisol Awakening Response (new)	553	8.07	-0.62 (-1.49, 0.12)	-0.62 (-1.49, 0.12)	-0.62 (-1.36, 0.12)	-0.62 (-1.36, 0.12)	-0.62 (-1.24, 0.12)

^aUnadjusted

^bAdjusted for child age at outcome and sex

^cAdditionally adjusted for maternal age, maternal prenatal BMI, and SES

^dAdditionally adjusted for mother ever having smoked

^eAdditionally adjusted for birthweight and gestational age