Published in final edited form as:

Psychiatry Res. 2018 September ; 267: 243–248. doi:10.1016/j.psychres.2018.05.056.

Season of Birth: A Predictor of ADHD symptoms in Early Midlife

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Abstract

Objective—In this longitudinal study, we applied linear regression analyses to examine season of birth as related to symptoms of attention deficit/hyperactivity disorder (ADHD) in early midlife.

Method—We gathered longitudinal data on a prospective cohort of community-dwelling men and women (N=548) followed from adolescence to early midlife.

Findings—The findings indicate that, as compared with participants who were born in the summer, those who were born in the spring (Beta = 0.34; t-statistic = 3.59; p<0.001) had significantly more ADHD symptoms. In addition, exposure to maternal cigarette smoking in adolescence significantly intensified (p<0.01) the association between season of birth and ADHD symptoms in early midlife.

Conclusion—These findings suggest that exposure to greater maternal maladaptive behaviors, such as cigarette smoking, may result in a greater vulnerability to other environmental risk factors, such as season of birth.

1. INTRODUCTION

Attention-deficit/hyperactivity disorder (ADHD), which shows some stability across the life span (Kessler et al., 2010), is a major neuropsychiatric disorder diagnosed in children, adolescents, and adults. The adult literature suggests that ADHD is associated with higher health care costs (Hodgkins et al., 2011), cigarette smoking and substance-use disorders (Wilens et al., 2011), a greater prevalence of psychiatric disorders (Mannuzza et al, 1993; Hodgkins et al., 2011; Wilens et al., 2011), decreases in work performance and work productivity (Kessler et al, 2005; Biederman and Faraone, 2006), and lower educational attainment (Mannuzza et al, 1993).

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Conflict of Interest

The authors report no conflict of interest.

Despite a strong hereditary predisposition to ADHD, it is estimated that environmental factors account for 10% to 40% of the variance of this disorder (Banerjee et al., 2007). Season of birth may represent a significant environmental factor for ADHD. Some investigators have found that season of birth is associated with life-long psychiatric illnesses, including, notably, schizophrenia (Videbech et al., 1974; Bradbury and Miller, 1985; Boyd et al., 1986; Mortensen et al., 1999; Parker et al., 2000; Pedersen and Mortensen, 2001; Davies, et al., 2003; Tochigi et al., 2004; Demler, 2011), substance dependence (Kell, 1995; Levine and Wojcik, 1999; Goldberg and Newlin, 2000; Riala et al., 2009), and depression (Jewell et al., 2010; Park et al., 2016). Most of these studies found that on average, individuals born in the winter or the spring (December – May) are more likely to have later psychiatric illnesses. Season of birth has also been considered as a potential risk factor for ADHD (Mick et al., 1996; Brookes et al., 2008; Kowalyk et al., 2012; Morales et al., 2012; Krabbe et al., 2014; Pottegård et al., 2014). Overall, the findings with regard to this association are mixed and the mechanisms are not fully understood. For example, Liederman and Flannery (1994) found that spring or summer births increased the likelihood of later ADHD, while Mick et al. (1996) found that overall season of birth was not associated with ADHD, even though season of birth may be related to some subtypes of ADHD, such as those without psychiatric comorbidity. Seeger et al. (2004) found that season of birth strengthens the association between the Dopamine D4 Receptor gene (DRD4) 7-repeat allele and ADHD. However, using a larger sample, Brookes et al. (2008) did not confirm that interactive effect.

The objective of this study was to examine the associations between season of birth and symptoms of ADHD among a longitudinal sample of men and women in early midlife (mean age=43). In the present study, in addition to gender and age, we controlled for parental educational level, parental income, and the participant's educational level. Given that earlier psychosocial adversity, particularly exposure to maternal maladaptive behaviors/attributes, may represent another set of environmental risk factors for ADHD in the offspring (Biederman et al. 2002; Counts et al., 2005; Nigg et al., 2010; Max et al., 2013), we also examined the interactive effects between season of birth and earlier maternal factors in adolescence on adult symptoms of ADHD. Based on Family Interactional Theory (FIT, Brook et al., 1990), we focused on some important maternal behaviors and attributes in adolescence as they relate to later symptoms of ADHD. These factors include: maternal cigarette smoking and maternal internalizing (i.e., low self-control, depressive mood) and externalizing behaviors (i.e., rebellion). The following hypotheses guide the model testing procedure:

- Hypothesis 1** Season of birth is associated with later elevated symptoms of ADHD for individuals in early midlife.
- Hypothesis 2** Exposure to maternal cigarette smoking and maternal internalizing and externalizing behaviors in adolescence is associated with elevated symptoms of ADHD for individuals in early midlife independent of season of birth.
- Hypothesis 3** Exposure to maternal cigarette smoking and internalizing and externalizing behaviors in adolescence, which serve as moderators,

will strengthen the adverse effects of certain season of birth (e.g., born in the spring) on adult symptoms of ADHD.

2. METHODS

2.1. Participants and Procedure

Data on the participants in this study come from a community-based random sample residing in one of two upstate New York counties (Albany and Saratoga) first assessed in 1983. Albany and Saratoga have a humid continental climate, with cold, snowy winters, and hot, wet summers. The participants' mothers were interviewed about the participants in 1975 to assess psychosocial development among youngsters, when the mean age of the participants was 5 years. The sampled families were generally representative of the population of families in the two upstate New York counties. There was a close match of the participants on parental income, maternal education, and family structure with the 1980 census.

The present analysis (N=548) is based on data from Time 2 (T2; 1983) and Time 8 (T8; 2012–2013) of this longitudinal study. Participants consisted of N=548 mother-offspring pairs. The mean age of the mother participants at T2 was 40.0 years (SD=6.2). The offspring participants' mean ages (SDs) at the follow-up interviews were 14.1 (2.8) at T2 and 43.0 (2.8) at T8.

Extensively trained and supervised lay interviewers administered individual structured maternal interviews and offspring interviews at T2 (participants were interviewed in private). Questionnaires were self-administered by offspring participants at T8. Written informed consent and HIPAA authorization were obtained from all participants. The procedures used in this research study at T8 were approved by the Institutional Review Board of the New York University School of Medicine. Earlier waves of data collection at T2 were approved by the Mount Sinai School of Medicine Institutional Review Board. Additional information regarding the study methodology and measurements in varied domains are available in prior publications (e.g., Brook et al., 1986; Brook et al., 1990).

The participants who did not participate in the study in 2012–2013 (N = 208) were excluded from the analyses. There was a higher percentage of females (55% in the sample of 548 participants vs. 40.5% in the sample of 208 non-participants; $\chi^2(1) = 16.3$, p -value < 0.001). There were no associations between those included in the analysis (N = 548) as compared with those who were excluded (N = 208) from it with respect to age, T2 maternal cigarette smoking, T2 maternal depressive mood, T2 maternal low self-control, and T2 maternal rebellion ($p > 0.05$), as well as season of birth [$\chi^2(3) = 2.51$, p -value = 0.47] and county of origin [$\chi^2(1) = 0.23$, p -value = 0.63].

2.2. Measures

2.2.1. Dependent Variables

Symptoms of ADHD: In 2012–2013, the participants responded to questions with regard to their ADHD symptoms (Kessler et al., 2005). There are 6 items scored on a five-point scale:

never (0) to very often (4); $\alpha = .80$; i.e. (1) How often do you have trouble wrapping up the final details of a project, once the challenging parts have been done?; (2) How often do you have difficulty getting things in order when you have to do a task that requires organization?; (3) How often do you have problems remembering appointments or obligations?; (4) When you have a task that requires a lot of thought, how often do you avoid or delay getting started?; (5) How often do you fidget or squirm with your hands or feet when you have to sit down for a long time?; and (6) How often do you feel overly active and compelled to do things, like you were driven by a motor? The mean of the 6 items was used in the analysis.

2.2.2. Independent Variables

Season of Birth: The participants in this longitudinal study came from one of two upstate New York counties, i.e., Albany and Saratoga. According to the Köppen-Geiger climate classification (Kottek et al., 2006), Albany and Saratoga counties belong to the humid continental climate zone, which are characterized by changeable weather, hot summers and cold and long winters. Winter-like conditions prevail from December through March (the average low temperatures are below 32°F). Based on the historical average monthly temperatures in Albany and Saratoga counties (Arguez et al., 2012), the birth month of each participant was then categorized into one of the four seasons: Spring (April–May), Summer (June–August), Autumn (September–November), and Winter (December–March).

T2 Maternal Cigarette Smoking and Maladaptive Behaviors/Attributes: At T2, the mother participants reported the frequency of their current cigarette smoking (Johnston et al., 2006). The frequency was rated as none (0) - more than one pack a day (5). For T2 maternal maladaptive behaviors/attributes, we included a measure of low self-control which assesses emotional control (seven items, $\alpha=0.62$; e.g., “I rarely rely on careful reasoning in making up my mind.” [Brook et al., 1990]), a measure of rebellion (eight items, $\alpha=0.71$; e.g., “When rules and regulations get in the way, you sometimes ignore them.” [Smith and Fogg, 1979]), and a measure of depressive mood (five items, $\alpha=0.79$; e.g., “Over the last few years, how much were you bothered by feeling low in energy or slowed down?” [Derogatis et al, 1994]).

2.2.3. Control Variables—Control variables included in the present study were: Gender (male =1), T8 age (mean age = 43), T2 parental educational level (number of years of schooling), T2 household income (\$US), and county of origin (Albany county =1; Saratoga county = 0).

2.3. Analysis

The Statistical Analysis Software (SAS) program was used in the present analysis. Given that we performed multiple testing of several groups and several potential moderators, there is an increased risk for committing a Type I error due to alpha inflation. Therefore, for all of our statistical tests, we set the statistically significant level at $\alpha=0.01$. First, Pearson’s correlation analyses were conducted to examine the associations between each of the maternal variables (e.g., maternal cigarette smoking) and symptoms of ADHD. Second, we conducted a multivariate Ordinary Least Squares analysis to investigate the associations between season of birth and symptoms of ADHD. We included three indicator variables of

winter birth (December – March), spring birth (April – May), and autumn birth (September – November), with summer birth (June – August) as the reference. Gender, T8 age, T2 parental educational level, T2 household income, and county of origin were included as control variables. Third, for each maternal variable, we conducted a multivariate Ordinary Least Squares analysis by including the main effects (i.e., three season of birth variables and the maternal variable), three interactive terms, each of which represents the interactive effect between the maternal variable and one of the season of birth variables, and the control variables cited above. Fourth, we also conducted a multivariate Ordinary Least Squares analysis by including seven main effects (three SOB indicator variables and four maternal factors), twelve interactive terms, and five control variables (gender, T8 age, T2 parental educational level, T2 household income, and county of origin) in the regression equation.

3. RESULTS

Table 1 presents the mean (*SD*) or percentage (%) of the dependent and independent variables used in the present study. Pearson correlation analysis shows that there are trends that T2 maternal cigarette smoking ($r=0.07$, $p<0.10$), T2 maternal depressive mood ($r=0.08$, $p<0.10$), and T2 maternal low self-control ($r=0.09$, $p<0.05$) were positively associated with T8 symptoms of ADHD.

Table 2 presents the results of a multivariate Ordinary Least Squares regression with three season of birth indicator variables and control variables (T8 age, gender, T2 parental educational level, T2 household income, and county of origin) included. As shown in Table 2, as compared with participants who were born in the summer, those who were born in the spring (Beta = 0.34; t -statistic = 3.59; $p<0.001$) had significantly more ADHD symptoms.

Table 3 presents the results of separate multivariate Ordinary Least Squares regression analyses with main effects, interactive terms, and control variables (T8 age, gender, T2 parental educational level, T2 household income, and county of origin) included. As shown in Table 3, T2 low maternal self-control ($p<0.01$) and maternal cigarette smoking ($p<0.01$) significantly intensified the association between season of birth and ADHD symptoms in early midlife. Specifically, T2 low maternal self-control was significantly associated ($p<0.01$) with an increased difference in ADHD symptoms between those who were born in the autumn and those who were born in the summer. In addition, T2 maternal cigarette smoking was significantly associated ($p<0.01$) with an increased difference in ADHD symptoms between those who were born in the spring and those who were born in the summer (also see Figure 1).

Table 4 presents the results of the multivariate Ordinary Least Squares regression with all maternal factors and their interactions with season of birth included. As shown in Table 4, T2 maternal cigarette smoking was still significantly associated ($p<0.01$) with an increased difference in ADHD symptoms between those who were born in the spring and those who were born in the summer.

4. DISCUSSION

This study is among the first to investigate the associations between season of birth and symptoms of ADHD in early midlife using prospective, longitudinal follow-up data. We also examined the interactive effects between season of birth and earlier maternal cigarette smoking and maladaptive behaviors and attributes on adult ADHD. Overall, our hypotheses were partially supported by the data.

As regards season of birth, the present research provides evidence for a strong association between individuals born in the spring and greater symptoms of ADHD in early midlife, as compared with those who were born in the summer. Research has postulated that children born in the spring have an excess of psychiatric disorders later in life, including ADHD. This might be partially caused by seasonal factors such as meteorological factors. Findings of some studies suggest that early life seasonal factors influence later outcomes through the process of developmental plasticity (e.g., Barker and Osmond, 1986; Gluckman et al., 2004; Barker and Bagby, 2005). Developmental plasticity is defined as the phenomenon by which one genotype can give rise to a range of different physiological or morphological states in response to different environmental conditions during development. Individuals born during different seasons may experience different early developmental conditions, which act through the process of developmental plasticity, and alter development of the organism to such an extent that its capacity to cope with the environment of adult life is affected.

As reviewed by Tochigi et al. (2004), these seasonal factors consist of meteorological factors (such as ambient temperature, humidity, and hours of bright sunshine), the increase in the occurrence of several infections, nutrition, external factors such as heavy metals, factors on the paternal side such as sperm quality, maternal hormones, infant development after birth, and seasonal variation of procreation. First, according to the hypothesis formulated by Huntington (1938), temperature, in particular high temperature at the time of conception, causes the differences in the life span by weakening the “germ plasma”. As temperatures are experienced the highest in July/August in northern New York State, infants born in April-May (conception in July/August) may be disadvantaged. Second, infants born in the colder months of the year are more likely to be exposed to viruses and infectious agents later in pregnancy and thus may be at higher risk for later mental health problems. Third, the nutrition of the mother during pregnancy and of the baby in the first year of life may be the mechanism that underlies the effect of season of birth. For example, Lippi, Bonelli et al. (2015) found that participants born in colder seasons have a total vitamin D concentration in adulthood that is significantly lower than those born in seasons with longer daylight periods.

Some researchers, however, believe that the associations between season of birth and later outcomes are mainly explained by educational attainment and family social class (e.g., Angrist and Krueger, 1990; Buckles and Hungerman, 2013). In an influential study, Angrist and Krueger (1990) claimed that season of birth is related to educational attainment because of school policies of age at starting school and compulsory school attendance laws. Individuals born in the beginning of the year start school at an older age, and can therefore drop out after completing less schooling than individuals born near the end of the year. However, Bound and Jaeger (2000) present evidence suggesting Angrist and Krueger’s

interpretation is not well-founded. They showed an association between season of birth and earnings in cohorts that were not bound by compulsory school attendance laws. In the present study, we did not find the association between individuals born in the beginning of the year and greater symptoms of ADHD in early midlife, as compared with those who were born in other seasons.

Our results are consistent with FIT which emphasizes the moderating role played by maternal factors in assessing ADHD. The maternal moderators in this study include maternal cigarette smoking. According to Family Interactional Theory (FIT, Brook et al. 1990), the primary developmental context is the family. The major mechanisms linking the domains within FIT are social modeling, attachment, and the emulation of and identification with values and behaviors of parental figures as a result of this attachment. Attachment to and identification with well-adjusted parents, in turn, are directly or interactively related to well-adaptive behaviors. In contrast, when parents do not model conventionality, the children are more likely to exhibit maladaptive behaviors, such as symptoms of ADHD, or are more vulnerable to the influences of other risk factors. FIT also hypothesizes that maternal maladaptive behaviors and attributes often have far-reaching effects on an individual's adult life.

With regard to maternal cigarette smoking, evidence has shown that maternal smoking during pregnancy is associated with an increased risk for ADHD in the offspring (McGee and Stanton, 1994; Milberger et al., 1996; Mick et al., 2002; Langley et al., 2005). Some investigators also found that postnatal exposure to secondhand smoke is associated with a higher likelihood of ADHD (Max et al., 2013; Tandon et al., 2014). However, the association between maternal smoking and offspring ADHD may not be causal (e.g., Obel et al., 2016). It is still unclear whether maternal smoking is likely to cause offspring ADHD symptoms, or whether maternal smoking is a marker of shared risk between mother and child (Brookes et al., 2006; Thapar et al., 2003). This issue may also apply with regard to other maternal potentially moderating variables. Therefore, although our results show significant interactive effects of maternal cigarette smoking with season of birth on adult ADHD symptoms, it is not possible to separate the effects of genetic and environmental influences in our measures of maternal cigarette smoking.

4.1 Limitations

Some limitations should be noted. First, even though the validity of the adult ADHD symptom measure is well established in the literature (Kessler et al., 2005; Kessler et al., 2007), the measure of adult ADHD symptoms may not identify some of those with low or moderate levels of symptoms who actually have ADHD (Kessler et al., 2005). Second, this study did not have data indicating whether or not those with ADHD were treated with medicine and/or other therapeutic interventions. Hence, whether such treatment was associated with the relationship of season of birth to the presence of ADHD symptoms in adulthood could not be assessed. Third, we used a single self-report measure of adult ADHD symptoms at T8. We cannot rule out the possibility that the association between season of birth and adult ADHD symptoms may reflect a third common factor, such as genetic factors. Fourth, this study is limited because the sample was comprised of predominantly white

participants. Therefore, the findings may not be generalizable to racial/ethnic minority groups or individuals living in other parts of the country. Fifth, some participants were lost due to attrition. Had these nonparticipants been included in the analyses, it might have resulted in greater variability, which may have strengthened the results. There was a trend between maternal cigarette smoking and ADHD.

4.2 Strengths

Despite these limitations, this study has several strengths. Rather than using retrospective data to answer questions about participants when they were children, this study is strengthened by the use of longitudinal data and maternal reports. The results of this research emphasize the significance of taking a lifespan perspective when identifying the predictors of symptoms of ADHD. Moreover, some published ADHD studies have used samples from psychiatric clinics, which may have higher levels of comorbidity (Biederman et al., 2006). This study used a substantial community sample currently in their early 40s, a sample larger and older than most studies assessing smoking and adult ADHD symptoms. To our knowledge, it is the only study to examine the role of season of birth as an independent variable in the context of maternal factors related to adult symptoms of ADHD.

4.3 Conclusions

Even though the main effect of maternal cigarette smoking on adult symptoms of ADHD was not significant, this study contributes to the literature by showing that season of birth and early maternal cigarette smoking significantly interacted in relation to adult symptoms of ADHD. Individuals who were born in the spring and whose mothers smoked cigarettes reported more symptoms of ADHD in early midlife. These findings suggest that exposure to greater maternal maladaptive behaviors may result in a higher vulnerability to other environmental risk factors, such as season of birth. Thus, these findings further provide support for the contribution of season of birth and exposure to maternal maladaptive behaviors to the risk for ADHD in early midlife.

Acknowledgments

This research was supported by NIH grants DA032603 from the National Institute on Drug Abuse, and CA122128 from the National Cancer Institute, awarded to Dr. Judith S. Brook.

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Figure 1.
Interactive Effect between Spring Births and Maternal Cigarette Smoking on Adult ADHD Symptoms as Compared to Summer Births.

Table 1

Descriptive Statistics of the Control Variables (N=548)

Variables	Coding	Mean (SD), Median, or %
<i>Dependent Variable</i>		
T8 Symptoms of ADHD	Never (0) - Very often (4)	1.14 (0.70)
<i>Independent Variables</i>		
Winter (December – March)	No (0) – Yes (1)	33.2%
Spring (April – May)	No (0) – Yes (1)	15.5%
Summer (June – August)	No (0) – Yes (1)	25.6%
Autumn (September – November)	No (0) – Yes (1)	25.7%
T2 Maternal Cigarette Smoking	None (0) – More than 1 pack a day (4)	2.24 (1.57)
T2 Maternal Depressive Mood	Not at all (1) – Extremely (5)	2.1 (0.68)
T2 Maternal Low Self Control	False (1) – True (4)	1.98 (0.47)
T2 Maternal Rebellion	False (1) – True (4)	1.82 (0.48)
<i>Control Variables</i>		
Gender	Female (0) – Male (1)	Male=45%
T8 Age	Years	43.01 (2.78)
T2 Family Income	\$US	\$25,000 ^a
T2 Parental Educational Level	Years of schooling	13.66 (2.47)
Albany county	No (0) – Yes (1)	Albany=45.3%

Note:

^a median income.

Table 2

Ordinary Least Squares Regressions: Season of Birth as Related to ADHD Symptoms in the Early Forties (N=548).

Independent Variables	ADHD Symptoms Beta (t-statistic)
Winter (December – March)	0.08 (0.98)
Spring (April – May)	0.34 (3.59) ***
Autumn (September – November)	0.17 (2.07) *
R ²	0.04

Note:

*
p<0.05;

p<0.001;

Born in the summer (June – August) was treated as a reference;

Gender, age, parental educational level, T2 household income, and county of origin were statistically controlled.

Table 3

Results of Separate Ordinary Least Squares Regressions: Interactions of Season of Birth and Maternal Factors as Related to ADHD Symptoms in the Early Forties (N=548).

Independent Variables	ADHD Symptoms Beta (t-statistic)
<i>Maternal Cigarette Smoking with Season of Birth</i>	
Maternal Cigarette Smoking × Winter	0.06 (1.25)
Maternal Cigarette Smoking × Spring	0.18 (2.92) **
Maternal Cigarette Smoking × Autumn	0.13 (2.34) *
<i>Maternal Depression with Season of Birth</i>	
Maternal Depression × Winter	0.05 (0.40)
Maternal Depression × Spring	0.13 (0.88)
Maternal Depression × Autumn	0.27 (2.05) *
<i>Maternal Low Self-Control with Season of Birth</i>	
Maternal Low Self-control × Winter	0.17 (1.00)
Maternal Low Self-control × Spring	0.13 (0.64)
Maternal Low Self-control × Autumn	0.50 (2.73) **
<i>Maternal Rebellion with Season of Birth</i>	
Maternal Rebellion × Winter	0.33 (1.95)
Maternal Rebellion × Spring	0.18 (0.90)
Maternal Rebellion × Autumn	0.45 (2.42) *

Note:

*
p<0.05;

**
p<0.01;

For each set of interactive effects, main effects (three SOB indicator variables and the maternal factor), three interactive terms, and the control variables (gender, T8 age, T2 parental educational level, T2 household income, and county of origin) were included in the regression equation;

Born in the summer (June – August) was treated as a reference.

Table 4

Results of Multivariate Ordinary Least Squares Regression: Interactions of Season of Birth and Maternal Factors as Related to ADHD Symptoms in the Early Forties (N=548).

Independent Variables	ADHD Symptoms Beta (t-statistic)
<i>Maternal Cigarette Smoking with Season of Birth</i>	
Maternal Cigarette Smoking × Winter	0.05 (0.86)
Maternal Cigarette Smoking × Spring	0.17 (2.64) **
Maternal Cigarette Smoking × Autumn	0.07 (1.22)
<i>Maternal Depression with Season of Birth</i>	
Maternal Depression × Winter	−0.05 (−0.35)
Maternal Depression × Spring	0.12 (0.65)
Maternal Depression × Autumn	0.09 (0.54)
<i>Maternal Low Self-Control with Season of Birth</i>	
Maternal Low Self-control × Winter	−0.003 (−0.01)
Maternal Low Self-control × Spring	−0.20 (−0.70)
Maternal Low Self-control × Autumn	0.26 (1.00)
<i>Maternal Rebellion with Season of Birth</i>	
Maternal Rebellion × Winter	0.30 (1.58)
Maternal Rebellion × Spring	0.23 (1.00)
Maternal Rebellion × Autumn	0.20 (0.89)

Note:

**
p<0.01;

Seven main effects (three SOB indicator variables and four maternal factors), twelve interactive terms, and five control variables (gender, T8 age, T2 parental educational level, T2 household income, and county of origin) were included in the regression equation;

Born in the summer (June – August) was treated as a reference.