Journal Pre-proof

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PII: S0022-3476(22)00698-9

DOI: https://doi.org/10.1016/j.jpeds.2022.07.042

Reference: YMPD 13097

To appear in: *The Journal of Pediatrics*

Received Date: 27 January 2022

Revised Date: 23 July 2022

Accepted Date: 28 July 2022

Please cite this article as: Lingasubramanian G, Corman H, Noonan K, Reichman NE, Gestational Age at Term and Teacher-Reported ADHD Symptom Patterns, *The Journal of Pediatrics* (2022), doi: https://doi.org/10.1016/j.jpeds.2022.07.042.

Gestational Age at Term and Teacher-Reported ADHD Symptom Patterns

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Conflict of Interest Disclosures: No conflicts of interest to disclose.

Funding/Support: This work was supported by the Eunice Kennedy Shriver National Institute of Child Health and Human Development of the National Institutes of Health (award R01HD090119); the National Center for Advancing Translational Sciences, a component of the National Institutes of Health under award number UL1TR003017; the U.S. Department of Health and Human Services/Health Resources and Service Administration under award number U3DMD32755; and the Robert Wood Johnson Foundation through its support of the Child Health Institute of New Jersey (Grant 74260).

Key words not in title: Term Births; Hyperactivity, Oppositional, Inattention

Abstract

Objective: To estimate associations between gestational age (GA) and teacher-reported ADHD-related symptom patterns at age 9 among children born at term (37–41 weeks).

Study design: A secondary data analysis of approximately 1,400 children in the Fragile Families and Child Wellbeing study, a U.S. birth cohort study that oversampled non-marital births, was conducted. At age 9, students were evaluated by their teachers using the Conners Teacher Rating Scale–Revised Short Form that included subscales for symptoms of hyperactivity, ADHD, oppositional behavior, and cognitive problems/inattention. Unadjusted and adjusted negative binomial and logistic regression models of associations between GA and teacher-reported scores were estimated.

Results: Each week of GA at term was associated with hyperactivity scores that were 6% lower (adjusted IRR: 0.94; 95% CI: 0.89–0.99) and ADHD and cognitive problems/inattention scores that were 5% lower (adjusted IRR: 0.95; 95% CI: 0.91–0.98 in both cases). Early-term birth (37–38 weeks) was associated with 23% higher hyperactivity scores (adjusted IRR: 1.23; 95% CI:1.07–1.41), 17% higher ADHD scores (adjusted IRR: 1.17; 95% CI: 1.05–1.30), and ~50% higher odds of scoring 1.5+ standard deviations above the sample mean for hyperactivity (adjusted OR: 1.51; 95% CI: 1.05–2.18) when compared to birth at 39-41 weeks. There were no significant associations between GA and oppositional behavior scores.

Conclusion: The findings add to growing evidence supporting current recommendations for delaying elective deliveries to at least 39 weeks and suggest that regular screenings for ADHD symptoms are important for children born at 37-38 weeks GA.

Abbreviations:

ADHD: Attention deficit hyperactivity disorder

CI: Confidence Interval

CTRS-RSF: Conners Teacher Rating Scale–Revised Short Form

FFCWB: Fragile Families and Child Wellbeing

GA: Gestational age

IRR: incidence rate ratio

LBW: Low birth weight

OR: Odds ratio

SGA: Small-for-gestational age

U.S.: United States

INTRODUCTION

Attention Deficit Hyperactivity Disorder (ADHD), one of the most common disorders of childhood that affects over 10% of school age children in the United States (U.S.),[1] manifests in early childhood with symptoms of hyperactivity, impulsivity, and/or inattention that affect cognitive, academic, behavioral, emotional, and social functioning.[2] Numerous studies have demonstrated links between preterm birth (<37 weeks),[3,4] even moderate or late-preterm birth (32–36 weeks),[5,6] and ADHD and other psychiatric disorders, with some evidence of dose-response associations.[5,7,8]

Lower gestational age (GA) is associated with neonatal morbidities[9,10] and adverse neurodevelopmental and educational outcomes,[11,12] even at term (37–41 weeks). Despite documented links between GA at term and outcomes associated with ADHD, few studies have investigated associations with diagnosis or symptoms of ADHD.

Studies of 6–19 and 6–20-year-olds born at term in Sweden and Finland, respectively, found that the odds of being prescribed ADHD medication[8] and being diagnosed with ADHD[15] were higher for individuals born early-term (37–38 weeks). In contrast, studies from Norway and the U.S. found no robust associations between GA at term and mother-reported symptom of ADHD at age 5 or hyperactivity or impulsivity at age 8,[13] or between early-term birth and diagnosis of and medication treatment for ADHD by adulthood,[14] having health insurance claims for ADHD disorders or developmental speech or language disorders by age 5,[16] and mother-reported ADHD symptoms (cognitive problems or inattention and hyperactivity) in children ages 3–9 years.[17]

In this study, we estimated associations between GA and teacher-reported ADHD symptom patterns at age 9 among infants born at term (37–41 weeks) from a national U.S. birth cohort study that oversampled non-marital births, collected information from maternal and newborn hospital medical records, and administered maternal and teacher surveys.

METHODS

Data

We use data from the Fragile Families and Child Wellbeing (FFCWB) study, a national birth cohort study that randomly sampled births in 75 hospitals in 20 large U.S. cities in 1998–2000. By design, ~3/4 of the mothers were unmarried. Face-to-face interviews were conducted with 4,898 mothers while still in the hospital after giving birth;[18,19] additional information was collected from mothers' and infants' medical records from the birth hospitalization in 61 of the hospitals. The availability of medical records depended primarily on administrative processes of hospitals rather than decisions of respondents to make their records available. Mothers who completed postpartum (baseline) interviews were re-interviewed 1, 3, 5, and 9 years later. During the 9-year follow-up, interviewers obtained consent to contact the children's teachers.

The eligible sample consisted of 3,089 singleton births born at 37–41 weeks of gestation with available medical record data (needed to ascertain GA) and no missing analysis variables from the postpartum survey (Figure 1; available at www.jpeds.com). Of those, cases with no teacher survey data were excluded. Incomplete teacher responses resulted in slightly different analysis samples across outcomes.

Measures

Gestational Age

We used two measures of GA, a continuous measure of completed weeks and an indicator for early-term (37–38 weeks) versus 39–41 weeks. To simplify the discussion, we refer to the reference category of 39–41 weeks as full-term even though it includes both full-term (39–40 weeks) and late-term (41 weeks) as distinguished by the American College of Obstetricians and Gynecologists and the Society for Maternal-Fetal Medicine.[20]

Outcomes

Teachers completed the Conners Teacher Rating Scale–Revised Short Form (CTRS-RSF) that consists of 28 items that can be used to score students on four subscales that reflect symptom patterns related to ADHD: hyperactivity, ADHD, oppositional, and cognitive problems/inattention. Cronbachs Alpha values for the four subscales in the FFCWB sample were 0.92, 0.95, 0.94, and 0.88, respectively,[21] and a meta-analysis found that the CTRS-RSF performed well in assessing symptoms of ADHD in non-clinical settings.[22] For the CTRS-RSF, teachers rated various behaviors of the child from 0 to 3 (0 = not true, 1 = just a little true, 2 = pretty much true, 3 = very much true).[21] For each subscale, the teacher's responses to relevant items were summed. If there were any missing responses ("I don't know," refused, etc.), the subscale score was set to missing.

The four subscales do not perfectly map to the core symptoms of ADHD (inattention, hyperactivity, and impulsivity) and the ADHD subscale (sometimes called the ADHD index) does not subsume the other subscales. The only item that is used verbatim in more than one of the subscales is "Excitable, impulsive," which is included in both the hyperactivity and ADHD subscales. Thus, each subscale reflects a unique set of symptom patterns that are associated to varying degrees with the diagnosis of ADHD. Sample sizes were 1,438, 1,422, 1,431, and 1,427, respectively, for analyses of the hyperactivity, ADHD, oppositional, and cognitive problems/inattention subscales (Figure 1).

Control variables

All adjusted models controlled for the child's sex, parity (first birth), and maternal characteristics including the mother's age, race/ethnicity, foreign-born status, education, marital status, and Medicaid coverage for the delivery (vs. private or other insurance), all assessed at baseline.

Statistical Analysis

First, to assess differences between the overall eligible sample and the study sample with available teacher survey data, we compared the largest analysis sample (1,438, for hyperactivity) to the cases in the full cohort (excluding multiples) of 4,803 that were not in that sample using t-tests (for binary variables) or chi-square tests (for categorical variables). Second, we calculated mean scores and ranges for the hyperactivity, ADHD, oppositional, and cognitive problems/inattention subscales as well as sample proportions with specific maternal characteristics, overall and by early-term vs. full-term. Third, we estimated unadjusted and adjusted negative binomial regression models of associations between GA and teacher-reported scores on each of the four subscales and report incidence rate ratios (IRRs) and 95% confidence intervals (CIs). The negative binomial functional form, a generalization of Poisson regression, is appropriate for modeling count data with a high level of dispersion. The adjusted models controlled for child sex and maternal characteristics. We then estimated corresponding negative binomial regression models of associations between early-term (vs. full-term) birth instead of week of GA and the same outcomes. Finally, we estimated unadjusted and adjusted logistic regression models for scoring 1.5 or more standard deviations above the sample mean, which we refer to as “high scores,” for each subscale and present odds ratios (ORs) and 95% CIs.

Supplementary models: (1) excluded children born small-for-gestational-age (SGA; <10th percentile of birth weight for GA); (2) excluded children who were low birthweight (LBW; < 2500g); (3) replicated the analyses using inverse probability weights to account for sample loss from the eligible sample of 3,088 cases; (4) further included indicators for any obstetric risk factor, any delivery complication, prenatal smoking, late prenatal care (initiated after first trimester), and cesarean section delivery; and (5) separated the 39–41 week group into 39–40 and 4 weeks.

Analyses were conducted using Stata Version 17.0. This study was approved by the Rutgers Biomedical and Health Sciences Institutional Review Board.

RESULTS

Mothers of children in the largest analysis sample (that for hyperactivity) did not differ significantly from those in the original cohort that were not in that sample in terms of education, race-ethnicity, marital status, first birth, or Medicaid, but were slightly younger (24.9 vs. 25.4 years), and less likely to be foreign-born (13.9 vs. 18.6%) (not shown in tables).

Early-term children had significantly higher scores than full-term children on the hyperactivity, ADHD, and cognitive problems/inattention subscales (Table I). Roughly half of the mothers (48%) in the largest sample were non-Hispanic Black, 63% had a high school education or less, and 76% were unmarried, reflecting the oversampling of non-marital births in the FFCWB study and strong associations between non-marital childbearing, poverty, and entrenched social disadvantages associated with racial minority status in the U.S.[23] (Table II; available at www.jpeds.com). Almost two-thirds of deliveries (63%) were covered by Medicaid.

In both unadjusted and adjusted negative binomial regression models, the continuous measure of GA in weeks was associated with significantly lower scores on the teacher-reported hyperactivity, ADHD, and cognitive problems/inattention subscales at age 9 (Table III; available at www.jpeds.com). The unadjusted IRR estimate of the association between week of GA and hyperactive subscale score was 0.92 (95% CI: 0.87–0.98), indicating that each additional week of GA at term, on average, was associated with an 8% lower score. Similarly, each additional week of GA at term was associated with 6% lower scores on both the ADHD and cognitive problems/inattention subscales (IRR: 0.94; 95% CI: 0.91–0.98 in both cases). Adjusting for maternal characteristics reduced the estimates to 6% lower scores for hyperactivity (IRR: 0.94; 95% CI: 0.89–0.99) and 5% for both ADHD and cognitive problems/inattention (IRR: 0.95; 95% CI: 0.91–0.98 in both cases). GA was not significantly associated with oppositional behavior scores, even in unadjusted models. These estimates are presented graphically with predicted scores and 95% confidence intervals by week of gestation for each model specification and subscale (Figure 2).

Negative binomial regression models with indicators for early-term (vs. full-term) instead of the continuous measure of GA also indicated significant associations between early-term and scores on both the hyperactivity and ADHD subscales (Table IV; available at www.jpeds.com). In adjusted models, early-term was associated with 23% (IRR: 1.23; 95% CI: 1.07–1.41) and 17% (IRR: 1.17; 95% CI: 1.05–1.30) higher scores on the hyperactivity and ADHD scales, respectively. Again, GA was not significantly associated with oppositional behavior scores, even in unadjusted models.

Covariate estimates were very similar when using the two different measures of GA (weeks or the indicator for early-term) (Table III and Table IV). Children of married mothers had lower scores on the hyperactivity, ADHD, and cognitive problems/inattention subscales than those with unmarried mothers. Scores were higher for children whose births were financed by Medicaid compared with those whose births were not financed by Medicaid, and for males compared with females. Scores on the oppositional and cognitive problems/inattention subscales were lower for children of mothers with higher levels education, and scores on the oppositional subscale were higher for children of non-Hispanic Black mothers than for children of non-Hispanic White mothers.

Children born early-term had approximately 1.5 times higher odds of having a high score (1.5 or more standard deviations above the sample mean) on the hyperactivity subscale compared with full-term children (adjusted OR: 1.51; 95% CI: 1.05–2.18), but none of the other adjusted logistic regression estimates for high scores were statistically significant at conventional levels (Table V; available at www.jpeds.com).

Supplementary models (results not shown unless indicated otherwise)

Supplementary models that excluded children born SGA or excluded children who were LBW produced estimates very similar to those in Table III (Table VI; available at www.jpeds.com). Using inverse probability weights to account for sample loss did not substantively or substantially change the estimates. Further adjusting for any obstetric risk factor, any delivery complication, prenatal smoking, late prenatal care, and cesarean section delivery did not substantively change any of the estimates. Separating the 39–41-week group into 39–40- and 41-weeks did not substantively change the estimates and 41 weeks was not statistically significant across the models evaluated.

DISCUSSION

Among infants born at term that were part of an urban population-based U.S. birth cohort study that oversampled non-marital births, longer gestational was associated with fewer teacher-reported ADHD-related symptoms at age 9.Children born at 37–38 weeks had hyperactivity scores that were 23% higher and ADHD scores that were 17% higher than those of children born at 39–41 weeks and had about 50% higher odds of having a hyperactivity score that was at least 1.5 standard deviations above the sample mean. GA was not significantly associated with oppositional behavior scores across the models evaluated. The stronger associations for hyperactivity than for the other clusters of symptoms may reflect the fact that hyperactivity is more prominent than inattention in younger populations.[2] The magnitudes of the associations are not trivial, as a randomized clinical trial that focused mainly on clonidine found that methylphenidate was associated with a 22% reduction in scores on the Conners Teachers Abbreviated Symptom Questionnaire (a 10-item abbreviated instrument assessing ADHD symptoms) among children who have been diagnosed with ADHD.[24]

The findings from this study are broadly consistent with those from population-based studies in Sweden and Finland that focused on individuals ages 6–19 and 6–20 years, respectively, and found that the odds of having been prescribed ADHD medication (Sweden)[8] and having been diagnosed with ADHD (Finland)[15] were higher for individuals born early-term compared with those born at later term. However, the findings from Sweden (for children born 1987–2000) and Finland (born 1991–2005) stand in contrast with those from a study in Norway of a much older cohort (born 1967–1987, before prenatal ultrasounds, which allow for more accurate assessments of GA, became widely used)[25,26] that early-term birth was not significantly associated with having been diagnosed and approved for medication treatment for ADHD.[14]

One of the two previous U.S.-based studies found that early-term birth was not associated with health insurance claims for ADHD disorders or developmental speech or language disorders by age 5 in a low-income cohort in South Carolina.[16] However, it should be noted that the median age of diagnosis of ADHD in the U.S. is 6.[27] Studies based on maternal reports of ADHD symptoms (at age 5 or 8 in Norway,[13] or in children ages 3–9 years whose mothers were recruited from prenatal clinics in Michigan[17]) also found no associations with early-term birth, but substantial discordance has been found between mother and teacher reports of ADHD symptoms,[28] and some of the children in these studies were quite young.

None of the previous studies focused on teacher reports, which provide a valuable perspective, in conjunction with maternal reports and physician evaluations, for the diagnosis of ADHD. Mother-reported symptoms generally reflect behaviors in the home or in small family or social groups, while teacher-reported symptoms reflect behaviors in a structured educational setting by professionals who work with a large number of children and observe the range of behaviors that students exhibit in classrooms.

The finding that the estimated associations between GA at term and ADHD symptoms were almost identical in supplementary analyses that excluded children who were SGA or LBW provides important context for studies examining associations between BW and ADHD-related outcomes. A meta-analysis found that lower BW was associated with higher levels of ADHD symptoms,[29] and several studies have focused on isolating associations between BW and children's behavioral outcomes independent of GA. For example, a study comparing twins in Sweden found that lower BW was associated with more inattentive and hyperactive-impulsive symptom severity using a parent-reported scale,[30] and a recent U.S. multi-site study, also using a parent-reported scale, found that associations between BW and attention problems persisted even after controlling for GA.[31] Our finding of significant associations between GA and ADHD-related outcomes independent of SGA or LBW suggests that GA plays a unique role, at least among children born at term and for teacher-reported ADHD symptom patterns in a largely disadvantaged population.

Biological associations between GA at term and ADHD symptoms are plausible. The pathogenesis of ADHD is not definitively known, but it is thought that genetic susceptibility, structural and functional neurological abnormalities, and environment all play roles.[32-35] Children with ADHD have reversed or absent asymmetry of the caudate nucleus, smaller cerebral and cerebellar volume, smaller posterior corpus callosum regions, and increased gray matter in the posterior temporal and inferior parietal cortices compared with children without ADHD.[36] Preterm infants are at increased risk for ADHD because of immature brain development. Active myelination and significant growth in various kinds of brain cells are observed between 34 and 40 weeks of gestation, contributing substantially to cortical volume and cerebellar development,[37,38] and important and rapid myelination and interconnections between subcortical and cerebral cortex regions occur specifically during the last weeks of gestation.[39-40] Infants born full-term may benefit from the additional 1–2 weeks of brain growth in utero compared with those born early-term.

Overall, this study contributes to the emerging literature on GA at term and children's neurodevelopmental and educational outcomes, and more specifically to the small literature on GA at term and ADHD-related outcomes, in two major ways. First, the use of rich data on births from 61 hospitals across the U.S. as part of a national urban birth cohort study allowed us to contribute to the extremely small and limited literature on GA at term and ADHD in the U.S. Second, the use of teacher-reported outcomes (in our case, from the CTRS-RSF, which is a validated instrument for assessing symptoms associated with ADHD in the school setting) is unique in the small literature on GA at term and ADHD, provides information from reporters that regularly interact with and observe the behavior of a large number children in a structured setting, and complements the existing studies that used maternal reports of symptoms or documentation of diagnoses and/or medication from administrative records.

The study is also subject to certain limitations. The initial sample was exclusively urban and non-marital births were oversampled in the FFCWB study, resulting in a largely disadvantaged sample; as such, the findings may not generalize to the U.S. overall. Given the importance of the topic and the dearth of existing literature focusing on children in the U.S., the findings from this study should be replicated and further explored. Causality cannot be firmly established in any observational study; despite the rich data and insensitivity of our estimates to alternative model specifications, it is possible that the estimates are biased by residual confounding. Loss to follow-up is another limitation, although supplemental analyses suggested minimal bias owing to attrition. The Conners teacher scales cannot be used to make clinical diagnoses, although symptoms in the school setting are intrinsically important outcomes.

The findings from this study highlight the importance of longer gestation and add to mounting evidence based on neonatal, developmental, and educational outcomes that early elective deliveries (<39 weeks) should be avoided. These findings also support the need for regular screenings for ADHD symptoms in children born early-term who might otherwise be overlooked because of their term-birth status.

Figure 2: Predicted scores by week of gestation and 95% confidence intervals from negative binomial unadjusted and adjusted regressions of associations between gestational age at term and scores on teacher-reported ADHD symptom patterns at 9 years

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Table I: Means, standard deviations, and ranges of scores on subscales of the Conners Teacher Rating Scale–Revised Short Form at 9 years, overall and by early-term and full-term birth

		Overall	Early-term (37–38 weeks)	Full-term (39–41 weeks)
	Range	Mean (s.d.)	Mean (s.d.)	Mean (s.d.)
Hyperactivity*	0–21	3.65 (4.72)	4.47 (5.27)	3.34 (4.45)
		N = 1,438	N = 399	N = 1,039
ADHD*	0–36	9.24 (8.84)	10.57 (9.59)	8.72 (8.47)
		N = 1,422	N = 400	N = 1,022
Oppositional	0–15	2.13 (3.52)	2.41 (3.72)	2.02 (3.43)
		N = 1,431	N = 398	N = 1,033
Cognitive problems/inattention*	0–15	4.53 (4.16)	4.95 (4.22)	4.36 (4.13)
		N = 1,427	N = 396	N = 1,031

Notes: s.d. = standard deviation. Ranges are the actual ranges in the data for each subscale, which are the same as the possible ranges.

*Statistically significant difference between early-term and full/late term at 5% level using a two-tailed t-test.

Table II: Sample characteristics, overall and by early-term and full-term birth

	Overall	Early-term (37–38 weeks)	Full-term (39–41 weeks)
Child sex			
Male	0.52	0.51	0.51
Maternal characteristics			
Non-Hispanic White*	0.22	0.17	0.23
Non-Hispanic Black*	0.48	0.52	0.46
Hispanic	0.27	0.25	0.28
Other non-White	0.04	0.06	0.03
< High school	0.32	0.33	0.32
High school graduate	0.31	0.30	0.32
Some college	0.26	0.28	0.25
College graduate	0.10	0.09	0.11
Foreign born	0.14	0.13	0.14
< 20 years old	0.19	0.18	0.20
20–35 years old	0.73	0.75	0.72
> 35 years old	0.08	0.08	0.08
Married	0.24	0.23	0.25
First birth*	0.38	0.34	0.40
Medicaid	0.63	0.66	0.62
N	1,438	399	1,039

Notes: Figures are column proportions. All maternal characteristics were measured before the child's birth or when the mother was in the hospital right after giving birth to the child. Sample characteristics were computed using the sample for analyses of the hyperactivity subscale.

* Statistically significant difference between early-term and full-term at 5% level using a two-tailed t-test.

Table III: Unadjusted and adjusted negative binomial regression estimates of associations between gestational age at term and teacher-reported ADHD symptom patterns at 9 years

		Hyperactivity IRR (95% CI)	ADHD IRR (95% CI)	Oppositional IRR (95% CI)	Cognitive problems/ inattention IRR (95% CI)
Unadjusted:					
Gestational age					
	Weeks	0.92*** (0.87 - 0.98)	0.94*** (0.91 - 0.98)	0.97 (0.91 - 1.04)	0.94*** (0.91 - 0.98)
Adjusted:					
Gestational age					
	Weeks	0.94** (0.89 - 0.99)	0.95*** (0.91 - 0.98)	0.99 (0.92 - 1.06)	0.95*** (0.91 - 0.98)
Child sex					
	Male	2.01*** (1.76 - 2.31)	1.74*** (1.57 - 1.93)	1.65*** (1.38 - 1.97)	1.23*** (1.12 - 1.36)
Maternal characteristics					
	Non-Hispanic Black	1.13 (0.93 - 1.37)	1.02 (0.88 - 1.18)	1.81*** (1.38 - 2.37)	1.07 (0.92 - 1.24)
	Hispanic	0.85 (0.68 - 1.07)	0.89 (0.75 - 1.06)	0.97 (0.70 - 1.35)	1.00 (0.85 - 1.18)

	Other non-White	0.69* (0.46 - 1.05)	0.77* (0.57 - 1.02)	1.23 (0.70 - 2.17)	0.76* (0.55 - 1.05)
	High school graduate	1.10 (0.93 - 1.31)	0.98 (0.87 - 1.12)	1.08 (0.88 - 1.34)	0.90* (0.80 - 1.01)
	Some college	1.09 (0.90 - 1.32)	0.97 (0.85 - 1.12)	1.00 (0.79 - 1.27)	0.81*** (0.71 - 0.93)
	College graduate	1.13 (0.81 - 1.57)	1.01 (0.79 - 1.30)	0.61** (0.39 - 0.97)	0.68*** (0.53 - 0.87)
	Foreign born	0.78* (0.60 - 1.02)	0.85 (0.70 - 1.03)	0.55*** (0.39 - 0.78)	0.93 (0.78 - 1.11)
	< 20 years	1.03 (0.74 - 1.45)	0.96 (0.76 - 1.23)	1.09 (0.73 - 1.63)	0.85 (0.68 - 1.05)
	20–35 years	1.04 (0.78 - 1.38)	0.95 (0.78 - 1.17)	1.12 (0.80 - 1.59)	0.84* (0.70 - 1.01)
	Married	0.68*** (0.56 - 0.83)	0.72*** (0.62 - 0.84)	0.79* (0.60 - 1.04)	0.78*** (0.67 - 0.91)
	First birth	1.04 (0.89 - 1.21)	1.02 (0.91 - 1.14)	0.99 (0.82 - 1.21)	0.91* (0.81 - 1.02)
	Medicaid	1.22** (1.04 - 1.43)	1.17** (1.03 - 1.32)	1.38*** (1.12 - 1.69)	1.21*** (1.07 - 1.36)
N		1,438	1,422	1,431	1,427

Notes: IRR = incidence rate ratio. Estimates are from Model 2 (for GA in weeks) of Table 3. *p < .10; **p < .05; ***p<.01.

Table IV: Unadjusted and adjusted negative binomial regression estimates of associations between early-term and teacher-reported ADHD symptom patterns at 9 years

		Hyperactivity IRR (95% CI)	ADHD IRR (95% CI)	Oppositional IRR (95% CI)	gnitive problems/ inattention IRR (95% CI)
Unadjusted:					
Gestational age					
	Early-term (vs. full-term)	1.34*** (1.16 - 1.54)	1.21*** (1.09 - 1.35)	1.19* (0.99 - 1.43)	1.13** (1.02 - 1.26)
Adjusted:					
Gestational age					
	Early-term (vs. full-term)	1.23*** (1.07 - 1.41)	1.17*** (1.05 - 1.30)	1.06 (0.88 - 1.27)	1.10* (0.99 - 1.22)
Child sex					
	Male	2.01*** (1.75 - 2.30)	1.74*** (1.57 - 1.93)	1.65*** (1.38 - 1.97)	1.23*** (1.12 - 1.36)
Maternal characteristics					
	Non-Hispanic Black	1.13 (0.93 - 1.37)	1.03 (0.89 - 1.19)	1.81*** (1.38 - 2.37)	1.07 (0.93 - 1.24)
	Hispanic	0.87 (0.69 - 1.09)	0.91 (0.76 - 1.08)	0.97 (0.70 - 1.35)	1.01 (0.85 - 1.19)
	Other non-White	0.69*	0.77*	1.23	0.76

		(0.46 - 1.05)	(0.57 - 1.03)	(0.69 - 2.16)	(0.55 - 1.06)
	High school graduate	1.10 (0.93 - 1.31)	0.98 (0.87 - 1.12)	1.08 (0.87 - 1.34)	0.91* (0.81 - 1.02)
	Some college	1.09 (0.90 - 1.31)	0.97 (0.85 - 1.12)	1.00 (0.79 - 1.27)	0.82*** (0.71 - 0.94)
	College graduate	1.11 (0.80 - 1.54)	1.01 (0.78 - 1.29)	0.61** (0.39 - 0.97)	0.69*** (0.54 - 0.88)
	Foreign born	0.78* (0.60 - 1.02)	0.85 (0.70 - 1.04)	0.55*** (0.39 - 0.78)	0.93 (0.79 - 1.11)
	< 20 years	1.01 (0.72 - 1.42)	0.95 (0.75 - 1.22)	1.09 (0.73 - 1.63)	0.84 (0.68 - 1.05)
	20–35 years	1.01 (0.76 - 1.35)	0.94 (0.77 - 1.16)	1.12 (0.79 - 1.58)	0.84* (0.70 - 1.00)
	Married	0.69*** (0.56 - 0.84)	0.72*** (0.62 - 0.84)	0.79* (0.60 - 1.05)	0.78*** (0.67 - 0.91)
	First birth	1.04 (0.89 - 1.21)	1.02 (0.91 - 1.14)	1.00 (0.82 - 1.22)	0.91* (0.81 - 1.01)
	Medicaid	1.20** (1.02 - 1.42)	1.16** (1.02 - 1.30)	1.38*** (1.12 - 1.69)	1.20*** (1.07 - 1.35)
N		1,438	1,422	1,431	1,427

Notes: IRR = incidence rate ratio. Estimates are from Model 4 (for early-term compared to full-term) of Table 3. *p < .10; **p < .05; ***p<.01.

Table V: Logistic regression estimates of associations between gestational age at term and high teacher-reported scores for ADHD symptom patterns at 9 years, using alternative measures of gestational age

		High Score (>=1.5 standard deviation above sample mean)			
Model		Hyperactivity OR (95% CI)	ADHD OR (95% CI)	Oppositional OR (95% CI)	Cognitive problems/ inattention OR (95% CI)
		(N = 1,438)	(N = 1,422)	(N = 1,431)	(N = 1,427)
Continuous measure of gestational age in weeks					
1	Unadjusted	0.90 (0.78 - 1.04)	0.91 (0.79 - 1.06)	0.97 (0.84 - 1.13)	0.88* (0.77 - 1.00)
2	Adjusted	0.91 (0.79 - 1.05)	0.93 (0.80 - 1.08)	1.01 (0.87 - 1.18)	0.89 (0.78 - 1.02)
Early-term, compared to full-term					
3	Unadjusted	1.57** (1.10 - 2.23)	1.43* (0.99 - 2.06)	1.21 (0.83 - 1.77)	1.23 (0.86 - 1.74)
4	Adjusted	1.51**	1.35	1.03	1.14

		(1.05 - 2.18)	(0.93 - 1.97)	(0.69 - 1.55)	(0.80 - 1.62)

Note: Adjusted models control for child sex and maternal characteristics in Table 2). *p < .10;

**p < .05.

Table VI: Fully-adjusted negative binomial regression estimates of associations between early-term and teacher-reported ADHD symptom patterns at 9 years, overall and excluding SGA or LBW cases

Model		Hyperactivity IRR (95% CI)	ADHD IRR (95% CI)	Oppositional IRR (95% CI)	Cognitive problems/ inattention IRR (95% CI)
Continuous measure of gestational age in weeks					
A	Adjusted estimates from Table 3	0.94** (0.89 - 0.99)	0.95*** (0.91 - 0.98)	0.99 (0.92 - 1.06)	0.95*** (0.91 - 0.98)
		N = 1,438	N = 1,422	N = 1,431	N = 1,427
B	Above model excluding SGA cases	0.93*** (0.88 - 0.98)	0.94*** (0.90 - 0.98)	0.99 (0.92 - 1.07)	0.95** (0.91 - 0.99)
		N = 1,305	N = 1,293	N = 1,299	N = 1,298
C	Above model excluding LBW cases	0.93*** (0.88 - 0.98)	0.94*** (0.90 - 0.98)	0.98 (0.91 - 1.06)	0.95** (0.91 - 0.99)
		N = 1,385	N = 1,370	N = 1,380	N = 1,379
Early-term, compared to full-term					

D	Adjusted estimates from Table 4	1.23*** (1.07 - 1.41)	1.17*** (1.05 - 1.30)	1.06 (0.88 - 1.27)	1.10* (0.99 - 1.22)
		N = 1,438	N = 1,422	N = 1,431	N = 1,427
E	Above model excluding SGA cases	1.27*** (1.10 - 1.46)	1.19*** (1.06 - 1.33)	1.05 (0.87 - 1.28)	1.08 (0.97 - 1.20)
		N = 1,305	N = 1,293	N = 1,299	N = 1,298
F	Above model excluding LBW cases	1.26*** (1.10 - 1.46)	1.19*** (1.07 - 1.33)	1.09 (0.90 - 1.32)	1.08 (0.97 - 1.20)
		N = 1,385	N = 1,370	N = 1,380	N = 1,379

Notes: IRR = incidence rate ratio. *p < .10; **p < .05; ***p<.01.

Figure 1: Derivation of Analysis Samples

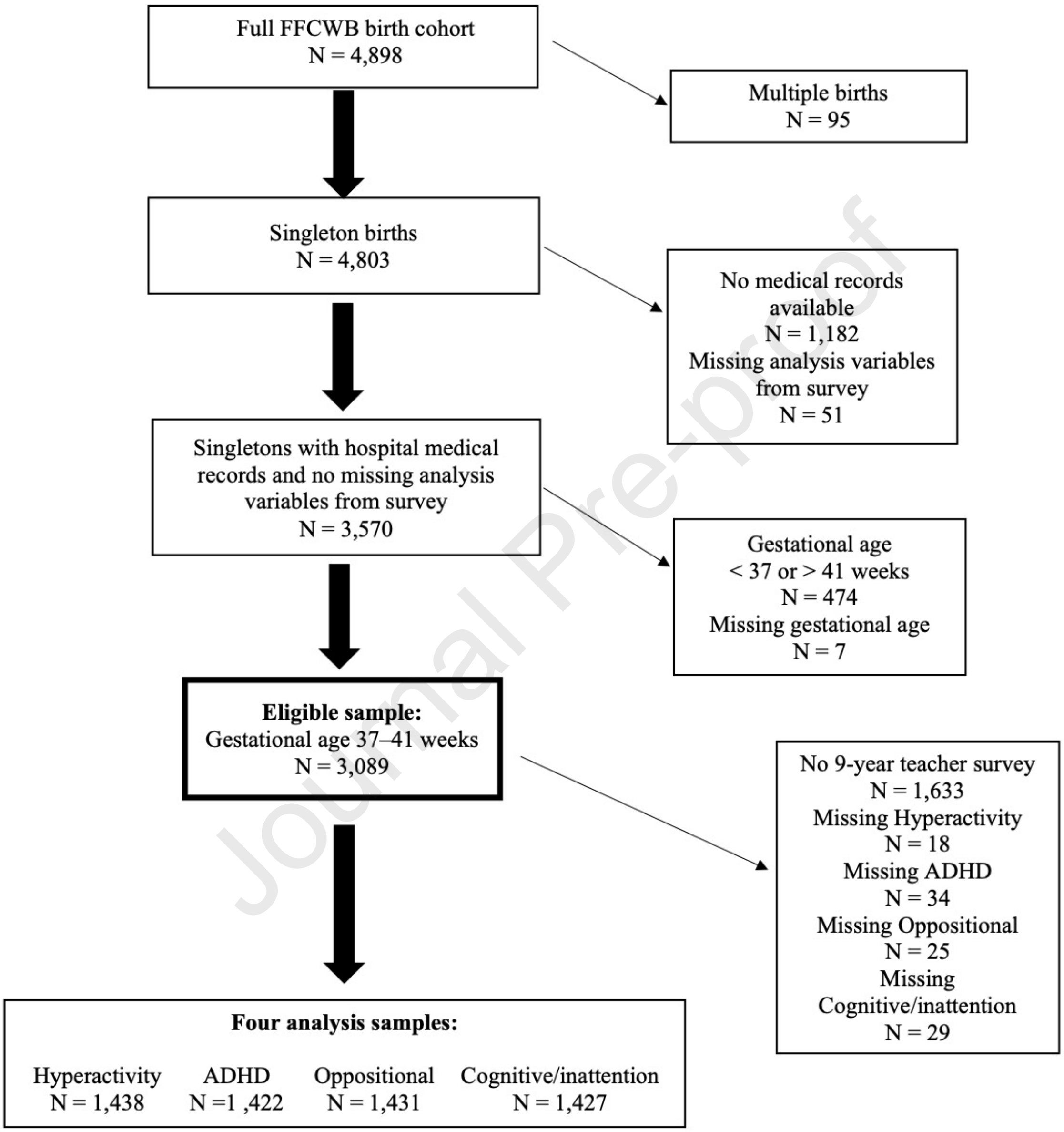
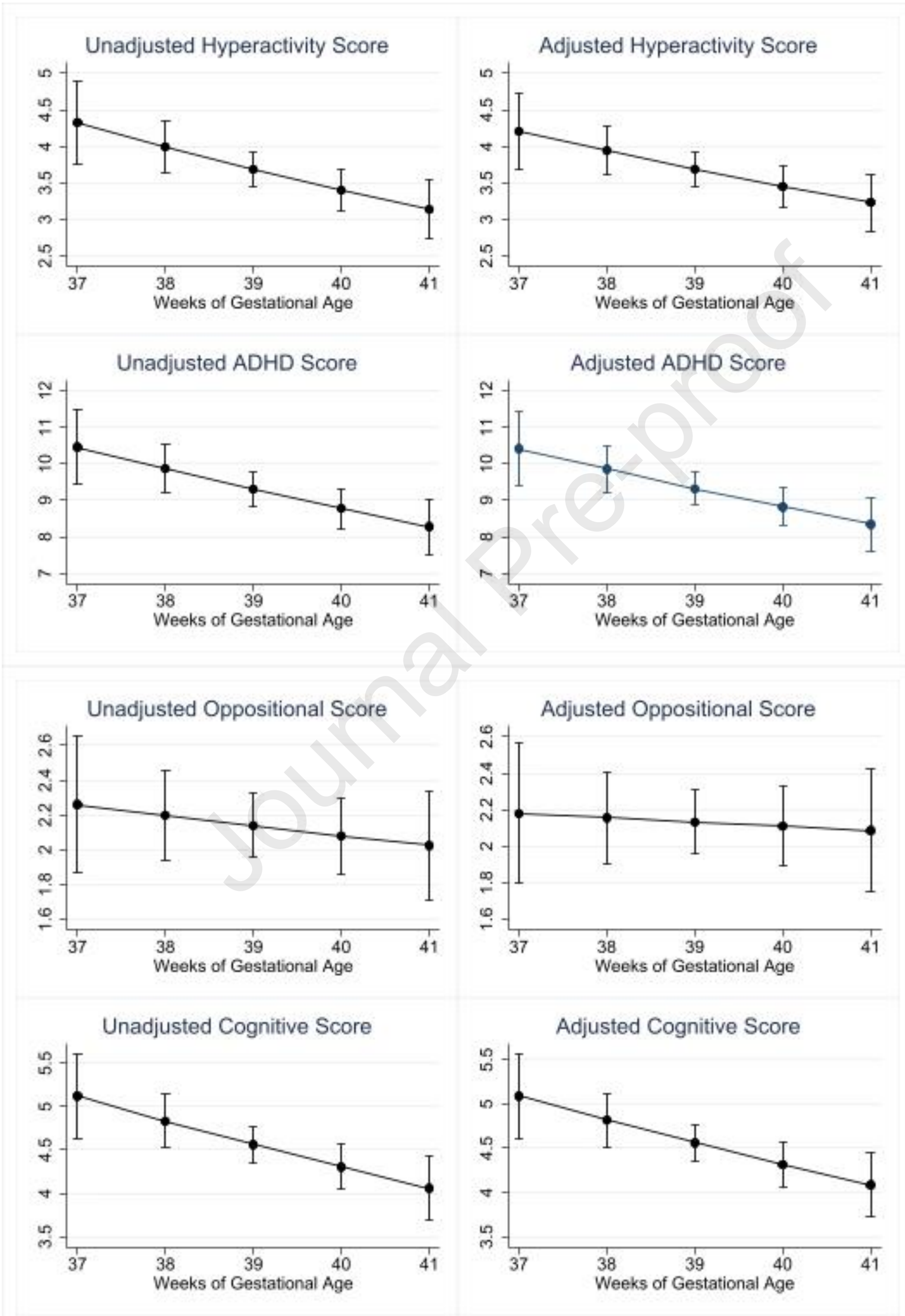


Figure 2: Predicted scores by week of gestation and 95% confidence intervals from negative binomial unadjusted and adjusted regressions of associations between gestational age at term and scores on teacher-reported ADHD symptom patterns at 9 years



Notes: Adjusted models control for child sex and maternal characteristics in Table 2. Full negative binomial unadjusted and adjusted estimates are presented in Table 3.

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	3-4
Objectives	3	State specific objectives, including any prespecified hypotheses	4-5
Methods			
Study design	4	Present key elements of study design early in the paper	4 & 7-8
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	5 & Fig. 1
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	5-7
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	5-7
Bias	9	Describe any efforts to address potential sources of bias	8 & 10
Study size	10	Explain how the study size was arrived at	5 & Fig. 1
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	5-7
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	7-8 & 10
		(*b*) Describe any methods used to examine subgroups and interactions	
		(*c*) Explain how missing data were addressed	
		(*d*) If applicable, explain how loss to follow-up was addressed	
		(*e*) Describe any sensitivity analyses	
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	5 & Fig. 1
		(b) Give reasons for non-participation at each stage	
		(c) Consider use of a flow diagram	
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	5 & Table I
		(b) Indicate number of participants with missing data for each variable of interest	
		(c) Summarise follow-up time (eg, average and total amount)	

	Table 1

		precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included (*b*) Report category boundaries when continuous variables were categorized (*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	
Discussion			
Key results	18	Summarise key results with reference to study objectives	9-10
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	12-13
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	13
Generalisability	21	Discuss the generalisability (external validity) of the study results	12-13
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	1

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at http://www.strobe-statement.org.