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# Population impact of preterm birth and low birth weight on developmental disabilities in US children

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## Abstract

**Purpose—**Although previous studies demonstrate associations between adverse perinatal outcomes and developmental disabilities (DDs), study of population impacts is limited.

**Methods—**We computed relative risks adjusted (aRRs) for sociodemographic factors and component and summary population attributable fractions (PAFs) for associations between very low birth weight (VLBW, all preterm births), moderately low birth weight (MLBW) + Preterm, MLBW at term, and normal birth weight (NBW) + Preterm and seven DDs (cerebral palsy [CP], autism spectrum disorder [ASD], intellectual disability [ID], behavioral-conduct disorders, attention-deficit-hyperactivity disorder [ADHD], learning disability [LD], and other developmental delay) among children aged 3–17 years in the 2011–2012 National Survey of Children's Health.

**Results—**VLBW-Preterm, MLBW-Preterm and NBW-Preterm were strongly to moderately associated with CP (aRRs: 43.5, 10.1, and 2.2, respectively; all significant) and also associated with ID, ASD, LD, and other developmental delay (aRR ranges: VLBW-Preterm 2.8–5.3; MLBW-Preterm 1.9–2.8; and NBW-Preterm 1.6–2.3). Summary PAFs for preterm birth and/or LBW were 55% for CP, 10%–20% for ASD, ID, LD, and other developmental delay, and less than 5% for ADHD and behavioral-conduct disorders. Findings were similar whether we assessed DDs as independent outcomes or within mutually exclusive categories accounting for DD co-occurrence.

**Conclusions—**Preterm birth has a sizable impact on child neurodevelopment. However, relative associations and population impacts vary widely by DD type.

### Keywords

Developmental disabilities; Premature birth; Infant; Low birth weight; Risk factor

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## Introduction

Developmental disabilities (DDs) are chronic conditions associated with significant impairments in physical, cognitive, behavioral, and/or speech/language functioning. The prevalence of DDs in US children is estimated at 15% overall [1] and ranges from less than 1% (e.g., cerebral palsy [CP]) [2] to 9% (e.g., attention-deficit-hyperactivity disorder [ADHD]) [3]. In addition to functional limitations, children with DDs have increased prevalence of many health conditions including asthma, eczema, gastrointestinal disorders, and obesity [4,5]. Although the causes of a few DDs are well defined (e.g., intellectual disability [ID] linked to select genetic conditions or fetal alcohol syndrome), for most DDs, etiology is complex and multifactorial [6–10].

Although numerous studies document associations between preterm birth (PTB) and low birth weight (LBW) and DDs such as CP [8,11,12], ID [12–17], autism spectrum disorder (ASD) [12,13,18], ADHD [12,19,20], learning disability (LD) [12,21], and general developmental delay [12,22,23], there is limited assessment of population impacts. Studies of population attributable fractions (PAFs) in US populations include an assessment of the Georgia Pregnancy Risk Assessment Monitoring System which estimated 42% of CP cases and 13% of ID cases were attributable to LBW [24], an assessment of North Dakota registry data which estimated 8% of ASD cases were attributable to low gestation and 8% were attributable to LBW [25], and an assessment of the Autism and Developmental Disabilities Monitoring Network which estimated 12% of ASD cases were attributable to PTB, LBW, and Cesarean delivery [26]. Studies from other countries of the impacts of various pregnancy complications and/or outcomes on ASD [27], ADHD [20], and developmental delays [28] reported moderate PAFs for the various perinatal factors studied. These past studies had notable limitations. Most did not assess the known overlap between the perinatal factors studied, all only assessed one or two DDs, and none assessed potential effects from co-occurring DDs. A high proportion of children with DDs meet diagnostic criteria for multiple DDs [29,30]. Boulet et al. [29] reported that 43%–96% of US children with specific DD diagnoses had more than one DD diagnosis.

Using data from the 2011–2012 National Survey of Children's Health (NSCH), we assessed associations and population impacts of PTB and LBW on subsequent DDs including CP, ID, ASD, ADHD, LD, behavioral or conduct problems or disorder (BCD), and other developmental delay. In addition to assessing a broad array of DDs side by side, we designed analyses to account for DD co-occurrence and examined a finer gradation of PTB and LBW risk than prior studies. To our knowledge, this is the largest and most comprehensive assessment of PAFs for DDs in a US population and the first-to-consider DD co-occurrence.

## Materials and methods

### Study population

The NSCH is a periodic random-digit-dial health survey of US noninstitutionalized children. Households are the primary sampling unit; from contacted households with children, one child is randomly selected. The survey is administered to a parent or guardian knowledgeable about the selected child's health. The overall response rate for the 2011–

2012 NSCH was 23% [31]. Nonresponse was more common for cell-phone numbers than landlines. Among contacted households with children, the interview completion rate was 54% and 41% for landline and cell-phone calls, respectively. An empiric assessment indicated that sampling weight nonresponse adjustment greatly reduced the maximum estimated bias for key survey indicators [31].

### Sample selection

From the 95,677 completed 2011–2012 NSCH interviews, we initially selected 81,590 children 3–17 years of age. We excluded younger children because most DDs are not diagnosed before the age of 3 years. We additionally excluded children missing data on DDs, birth weight, PTB, sex, and race-ethnicity, and children with implausible birth weight-PTB data. Our final sample size was 74,565.

### Ascertainment and categorization of DDs

We assessed CP, ASD, ID, BCD, ADHD, LD, and other developmental delay. Each DD was ascertained using two questions: “Has a doctor or other health care provider ever told you that [CHILD] had [CONDITION], even if [he/she] does not have the condition now?” and “Does [CHILD] currently have [CONDITION]?” Verbiage for the initial LD question was expanded slightly to include school officials in addition to health care providers. We classified children as having a given DD if the parent/guardian responded affirmatively to both questions.

To account for DD co-occurrence, we created mutually exclusive DD outcomes. For children for whom more than one DD was reported, the following order of precedence was used to determine the mutually exclusive outcome assignment: CP-ASD-ID-BCD-ADHD-LD-other developmental delay. With this ordering, DDs that typically have the most pervasive functional impacts and most well-established associations with LBW and PTB are given preference [11–16,29]. ASD was given preference over ID because a previous analysis demonstrated that associations between PTB/LBW and ASD with ID were more comparable to associations for ASD only than ID only [13]. This ordering also allowed us to assess the “other developmental delay” category without the contributing effects of other specific diagnoses.

Parents who reported their child had a DD were asked to rate the severity level (mild, moderate, or severe). No instructions were provided about how to assign the rating. We categorized each DD as mild or moderate-severe. We combined moderate and severe ratings because of sample size constraints and empirical assessments which indicated comparability in the results for these two categories.

### Perinatal risk factors

Respondents were asked: “What was [CHILD]’s birth weight?” and “Was [CHILD] born prematurely, that is, more than 3 weeks before [his/her] due date?” Response options for the birth weight question allowed for reporting in pounds, ounces, or grams. All data were converted to grams for analysis. We classified children as very LBW (VLBW)-Preterm (<1500 g, PTB = yes); moderately LBW (MLBW)-Preterm (1500–2499 g, PTB = yes);

MLBW-Term (1500–2499 g, PTB = no); normal birth weight (NBW)-Preterm (≥2500 g, PTB = yes); or NBW-Term (≥2500 g, PTB = no). NBW-Term served as the referent category. All VLBW births included in this analysis were preterm. We excluded 121 children (0.15%) classified as both VLBW and term as implausible because birth weights less than 1500 g are less than the third percentile of the expected birth weight distribution at 37 or more weeks' gestation [32].

### Potential confounders

Potential confounders were child age, sex, race-ethnicity, maternal education, and maternal age at child's birth. Because for both maternal age and education, there were moderate numbers of missing values, we created separate "missing" categories rather than exclude these children.

### Statistical analyses

In initial analyses, we compared distributions of potential confounders across the mutually exclusive DD groups and tested for general statistical differences using $\chi^2$ tests.

For core analyses, we assessed each DD two ways: as independent outcomes without consideration of co-occurring DDs and within the mutually exclusive categories that accounted for DD co-occurrence. For each DD outcome, we computed proportionate distributions of birth weight and gestational age and constructed logistic regression models to calculate adjusted relative risks (aRRs) and 95 percent confidence intervals (CIs) for associations with birth weight-gestational age factors. Using those data, we computed adjusted component PAFs which estimate population impact of each birth weight-gestational age factor on each DD outcome and summary PAFs which estimate the combined population impact of being born either LBW or PTB. CIs around PAF estimates were calculated using the Bonferroni inequality method [33].

In supplemental analyses, we estimated PAFs for mild versus moderate or severe DDs. Given the large US racial disparity in PTB [34], we also separately assessed non-Hispanic white (NHW) and non-Hispanic black (NHB) children. We did not examine other racial-ethnic subgroups because of sample size constraints. Subgroup analyses were based on DD outcomes without consideration of co-occurring DDs.

All estimates were weighted to reflect the US noninstitutionalized population of children. Standard errors were adjusted to account for the complex sample design with SAS-callable SUDAAN 11.0.0 software (Research Triangle Institute, Research Triangle Park, NC).

Human subjects review was not required for this secondary analysis of a deidentified data set.

## Results

Overall, 13.9% of children had one or more DD. Individual estimates ranged from 0.24% for CP to 8.2% for ADHD (Table 1). The percentage range for mutually exclusive DD categories was narrower: 0.24% for CP to 5.6% for ADHD. Overall, 49% of children with

DDs had greater than 1 DD and 23% had greater than 2 DDs. Thus, only 57% of children with ID, 34% of children with LD, and 13% of children with other developmental delay, were included in the respective mutually exclusive groups for these DDs.

The male-female ratio was greater than 1.0 for all groups other than CP and children without DDs (Table 2); the largest differential was observed for the ASD group. Children in the other developmental delay group were markedly younger than children without DDs, whereas children in all other DD groups were older. NHW race-ethnicity ranged from 44% (CP group) to 69% (ADHD group); maternal age at birth greater than or equal to 30 years ranged from 33% (BCD group) to 51% (other developmental delay group); and maternal education more than high school ranged from 43% (ID group) to 70% (ASD group).

Only 38% of CP cases occurred among children born NBW term compared with 69%–82% for other DDs and 86% for children without DDs (Table 3). The aRRs for associations between CP and VLBW-Preterm, MLBW-Preterm, and NBW-Preterm were 43.5, 10.1, and 2.2, respectively. The VLBW-Preterm and MLBW-Preterm PAFs for CP were 32.0% and 18.7%, respectively, and the PTB-LBW summary PAF for CP was 54.8%, all markedly higher than for any other DD.

ID, ASD, LD, and other developmental delay were also significantly associated with VLBW-Preterm (aRRs, 2.8–5.5), MLBW-Preterm (aRRs, 1.9–2.8), and NBW-Preterm (aRRs, 1.6–2.3; Table 3). Summary PAFs for these four DDs ranged from 10.2% to 19.1%. ADHD was modestly associated with VLBW-Preterm, MLBW-Preterm, and NBW-Preterm, and BCD was modestly associated with MLBW-Preterm only. The PAFs were much lower for these two DDs; summary PAFs for both were approximately 4%. None of the DDs were associated with MLBW-Term, and thus, the MLBW-Term component PAFs were all very low (<2%).

There were few differences in aRRs and component and summary PAFs between DDs assessed without consideration of co-occurrence and mutually exclusive DD outcomes (Table 3). CP findings were identical since CP was at the top of the mutually exclusive hierarchy. Findings for ASD, BCD, and ADHD were very similar for both classification schemes. Modest differences were observed for the other DDs. The PTB-LBW summary PAFs were 11% and 29% lower for the mutually exclusive LD and ID outcomes than the LD and ID outcomes not accounting for DD co-occurrence. Conversely, the summary PAF was 17% higher for the mutually exclusive other developmental delay outcome. These slight differences in PAFs were not completely unexpected since ID, LD, and other developmental delay were the three DDs for which we observed the largest shifts between number with DD irrespective of co-occurrence and number in mutually exclusive category (Table 1).

For all DDs except BCD, summary PAFs for conditions perceived by parents as being moderate or severe were higher than the summary PAFs for conditions perceived as mild (Table 4). For ASD, ID, and LD, these differences were marked; PAFs for DDs rated as moderate and/or severe were 2.5 to 3.8 times higher than PAFs for DDs rated as mild.

Although estimates were imprecise, summary PAFs for all DDs were higher for NHB than NHW children (Table 4). For ASD, BCD, ADHD, and LD, the PAFs were 2–3 time higher

for NHB children; for CP and other developmental delay, the PAFs were 50% higher; and for ID, the PAF was 10% higher. The primary reason for these differences was a higher proportion of LBW and PTB, most notably VLBW-Preterm, among NHB children rather than differential aRRs between NHB and NHW children (data not shown).

## Discussion

In this US nationally representative sample of children, PTB explained more than 50% of CP diagnoses, 15%–20% of ID and other developmental delay diagnoses, and 10%–15% of ASD and LD diagnoses. For CP, both aRRs and component PAFs showed a dose-response pattern: VLBW-PTBs explained substantially more CP than MLBW-PTBs, which explained substantially more CP than NBW-PTBs. For ASD, ID, LD, and other developmental delay, the VLBW-Preterm, MLBW-Preterm, and NBW-Preterm contributions were more evenly divided.

PTB had little impact on either ADHD or BCD prevalence; summary PAFs for both conditions were les than 5%. In addition, MLBW in the absence of PTB was not significantly associated with any DD and thus did not impact population prevalence.

All associations were independent of several sociodemographic factors. However, for all DDs, summary PAFs were higher for NHB than NHW children. Findings were similar whether we assessed each DD as an independent outcome or accounted for DD co-occurrence. It is particularly noteworthy that our findings for LD and other developmental delay are not explained by the known co-occurrence of these two diagnoses with other more specific and typically more pervasive diagnoses—CP, ASD, and ID. Nonetheless, PAFs were markedly lower for most DDs rated by parents as mild versus moderate or severe.

Our findings are consistent with previous studies reporting associations between PTB and LBW and CP, ID, ASD, ADHD, LD, general developmental delay, and lower scores on standardized achievement tests [8,12–23]. In addition, as with our study, previous studies have reported no or modest associations between late PTB and/or moderate LBW and ADHD [12,20,35]. Our findings are consistent with the few previous studies assessing the contributions of PTB and/or LBW on CP [24], ID [24], ASD [25,26], and ADHD [20]. Here, we expand on those early findings by examining the full spectrum of PTB and/or LBW and numerous DDs and considering how DD diagnoses co-occur among children.

We examined the theoretical question of what proportion of DDs could be eliminated if we could eliminate PTB and LBW births. We note, however, that these perinatal factors are heterogeneous, representing a composite of multiple potential underlying etiologic mechanisms. For example, it is unknown whether the associations between DDs and PTB are directly causal or represent another mechanism that may be common to both DDs and PTB, such as maternal infection or inflammation. These PAF estimates are thus best interpreted as the proportion of a given DD attributable to having a suboptimal perinatal environment resulting in VLBW-Preterm, MLBW-Preterm, MLBW-Term, or NBW-Preterm.

Despite the many study strengths, our findings should also be considered in light of limitations. DD diagnoses, birth weight, and PTB were parent reported. Nonetheless,

previous studies suggest high reliability for parent reporting of DDs, birth weight, and gestational age [36–39]. In addition, our PTB and LBW rates compare well with US natality data from the same birth cohorts as our study population (Appendix). We lacked data on a child's birth plurality and specific gestational age to further distinguish early from late PTB. However, we subdivided PTB into birth weight groups, known to be highly correlated with gestational age, particularly, VLBW [32]. Our DD severity measure, based on parent perception, was not well defined. Nonetheless, we observed a clear differential between DDs perceived as mild versus moderate-severe. Poor and/or inconsistent parent reporting would likely bias toward showing no difference between groups. Although we examined a comprehensive set of DDs, we did not include all DDs ascertained by NSCH because of insufficient sample sizes (e.g., Tourette's syndrome) and vague question verbiage (e.g., "hearing problems" and "vision problems that cannot be corrected with standard glasses or contact lenses"). While we did assess the more general diagnosis of "other developmental delay" and examined this diagnosis in the absence of other more specific DD diagnoses, we do not know whether some children with other developmental delay at the time of this survey were subsequently identified as having more specific DDs. Nor do we know the specific type of "other developmental delay." ID, ADHD, BCD, and LD are particularly likely to have been underdiagnosed in the youngest children (ages, 3–5 years). The survey response rate was low; however, sampling weights were adjusted for nonresponse. Moreover, our weighted estimates of PTB, LBW, and VLBW are closely aligned with those from US natality data (Appendix), and our estimates for two disabilities, ASD and ADHD, closely match independent estimates from the National Health Interview Survey [36,37]. Although we adjusted RRs for nonmodifiable demographic factors known to be associated with both PTB and DD, there was a modest level of missing values for maternal age and education. Nonetheless, for each DD, crude and aRRs were very similar (data not shown) indicating little confounding. Finally, PAF estimates are subject to imprecision; for example, the PAF and corresponding CI for ASD were 11.9% (5.6%–19.4%).

Beyond specific study limitations, PAF estimates should be interpreted in the context of potential limitations of the methodology generally including possible competing risks, survival time effects, censoring, and causality assumptions [40]. As described, a strength of our study is that we sought a priori to minimize these limitations. Because DDs commonly co-occur, and in some children not all individual, DDs are completely disentangled and diagnosed (i.e., diagnosis of one DD might be a "competing risk" for a second DD diagnosis), we analyzed multiple DDs side by side and assessed PAFs for each DD with and without consideration of co-occurring DDs. Given that the vast majority of our study population was 6 years or older, "survivorship" issues were minimized as most children had reached an age where nearly all DDs could be recognized. Still, we included children of 3–5 years in our study population because some DDs are diagnosed by age 3 years; this might have attenuated some estimates. Conversely, if children born VLBW were monitored more closely for DDs and diagnosed earlier than children born NBW term, this could have slightly inflated some PAF estimates, particularly for DDs with milder functional impacts. Although there is likely censoring of our outcomes due to fetal, infant, and early child death, this is a global problem for any analysis of DDs; even if the data source included fetal deaths, it would be problematic to count them in the denominator when they had no chance of being

included in the numerator. Finally, while PAF estimates assume a causal relationship between PTB and/or LBW and the fetal environments that bring about these adverse birth outcomes, we do not know of interventions to prevent the vast share of PTB and/or LBW. Nonetheless, PAF estimates provide valuable insight into population impacts.

## Conclusion

Despite recent declines, PTB remains common; 11.6% of US births in 2012 were preterm and 3.4% were very preterm (<37 and <34-week gestation, respectively) [34]. This study demonstrates the sizable contribution of PTB on child neurodevelopment. Efforts to control PTB are complex. Moreover, while our findings are informative on a population level, they do not indicate which PTB etiologic subgroups most contribute to the associations between PTB and DDs. Nonetheless, these findings highlight the need to minimize modifiable risk factors for PTB through comprehensive health care for women before and during their pregnancies.

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## Appendix

Comparison of NSCH Study sample with US population data on adverse perinatal outcome for same birth cohorts*

| Perinatal outcome | US natality data from published reports | | | | | | Current NSCH study sample (birth cohorts include 1994 to 2008) | |
|---|---|---|---|---|---|---|---|---|
| | 1994 | 1998 | 2001 | 2004 | 2006 | 2008 | Total study sample (weighted), *n* = 74,565 | Sample limited to children without DDs (weighted), *n* = 64,478 |
| % PTB | 11.0 | 11.6 | 11.9 | 12.5 | 12.8 | 12.3 | 11.5 | 10.5 |
| % LBW | 7.3 | 7.6 | 7.7 | 8.1 | 8.3 | 8.2 | 9.3 | 7.5 |
| % VLBW | 1.0 | 1.5 | 1.4 | 1.5 | 1.5 | 1.5 | 1.5 | 1.2 |

*There are some known differences in populations represented by NSCH and birth cohorts. NSCH data do not represent US children who died or migrated out of the country shortly after birth. Conversely, US birth cohort natality data do not include children who were born outside the United States and subsequently migrated into the United States.

**Table 1**

Developmental disability classification schemes and sample sizes: children 3–17 years of age, 2011–2012 National Survey of Children's Health

| Developmental Disability (without consideration of co-occurrence) | Total No. with diagnosis | % | Mutually exclusive DD categories | Total No. in mutually exclusive category | % | % of total with diagnosis included in mutually exclusive category |
|---|---|---|---|---|---|---|
| CP | 236 | 0.2 | CP | 236 | 0.2 | 100.0 |
| ASD | 1447 | 1.9 | ASD (no CP) | 1416 | 1.9 | 97.9 |
| ID | 862 | 1.1 | ID (no CP, ASD) | 492 | 0.6 | 57.1 |
| BCD | 1984 | 3.1 | BCD (no CP, ASD, ID) | 1446 | 2.3 | 72.9 |
| ADHD | 5962 | 8.2 | ADHD (no CP, ASD, ID, BCD) | 4198 | 5.6 | 70.4 |
| LD | 5603 | 7.8 | LD (no CP, ASD, ID, BCD, ADHD) | 1953 | 2.9 | 34.9 |
| Other developmental delay | 2608 | 3.4 | Other developmental delay (no CP, ASD, ID, BCD, ADHD, LD) | 346 | 0.4 | 13.3 |
| No developmental delay | 64,478 | 86.2 | No developmental delay | 64,478 | 86.2 | — |

**Table 2**

Percentage distributions* of sociodemographic characteristics by developmental disability category: children 3–17 years of age, 2011–2012 National Survey of Children's Health

| Characteristic | DD group—mutually exclusive categories | | | | | | | | *P* |
|---|---|---|---|---|---|---|---|---|---|
| | CP, *n* = 236 | ASD, *n* = 1416 | ID, *n* = 492 | BCD, *n* = 1446 | ADHD, *n* = 4198 | LD, *n* = 1953 | Other, *n* = 346 | None, *n* = 64478 | |
| Child sex | | | | | | | | | |
| Male | 41.0 | 82.9 | 59.3 | 68.2 | 67.6 | 53.2 | 61.1 | 48.7 | <.01 |
| Female | 59.0 | 17.1 | 40.7 | 31.8 | 32.4 | 46.8 | 38.9 | 51.3 | |
| Child age (y) | | | | | | | | | |
| 3–5 | 17.4 | 15.9 | 10.6 | 9.2 | 3.8 | 8.0 | 49.1 | 22.3 | <.01 |
| 6–11 | 35.0 | 45.5 | 39.2 | 45.3 | 41.7 | 40.7 | 43.5 | 39.0 | |
| 12–17 | 47.7 | 38.7 | 50.2 | 45.5 | 54.6 | 51.4 | 7.5 | 38.7 | |
| Child race-ethnicity | | | | | | | | | |
| Non-Hispanic white | 44.4 | 60.6 | 59.3 | 47.5 | 69.2 | 49.5 | 60.1 | 53.5 | <.01 |
| Non-Hispanic black | 25.6 | 11.1 | 20.6 | 21.6 | 12.6 | 15.3 | 9.5 | 13.6 | |
| Hispanic | 18.9 | 19.6 | 11.4 | 21.2 | 11.3 | 26.4 | 22.0 | 22.9 | |
| Other | 11.1 | 8.7 | 8.7 | 9.7 | 6.9 | 8.8 | 8.4 | 10.0 | |
| Maternal age at birth (y) | | | | | | | | | |
| 12–19 | 8.0 | 4.1 | 7.3 | 11.6 | 9.4 | 9.5 | 3.3 | 6.4 | <.01 |
| 20–29 | 41.2 | 43.2 | 37.1 | 43.9 | 44.7 | 44.6 | 41.2 | 43.9 | |
| 30–39 | 31.7 | 40.0 | 36.1 | 27.2 | 33.6 | 33.1 | 43.7 | 39.1 | |
| 40+ | 7.6 | 6.1 | 6.6 | 5.5 | 3.9 | 5.1 | 6.9 | 3.9 | |
| Missing | 11.5 | 6.6 | 13.0 | 11.8 | 8.4 | 7.7 | 4.9 | 6.8 | |
| Maternal education at time of survey | | | | | | | | | |
| <High school | 14.5 | 8.6 | 19.0 | 15.9 | 9.5 | 17.8 | 10.6 | 12.8 | <.01 |
| High school | 24.8 | 14.5 | 21.0 | 27.8 | 22.1 | 27.1 | 23.3 | 19.7 | |
| >High school | 50.2 | 70.5 | 42.7 | 44.1 | 60.3 | 47.3 | 63.2 | 61.3 | |
| Missing | 10.5 | 6.5 | 17.3 | 12.2 | 8.1 | 7.8 | 2.9 | 6.2 | |

*All estimates were weighted to reflect the US noninstitutionalized population of children.

*Ann Epidemiol*. Author manuscript; available in PMC 2017 April 01.

**Table 3**

Relative risks and component and summary population attributable fractions for associations between adverse perinatal outcomes and developmental disabilities: children 3–17 years of age, 2011–2012 National Survey of Children's Health

| Assessment of DDs without consideration of co-occurrence | | | | Assessment of DDs in mutually exclusive categories. | | | |
|---|---|---|---|---|---|---|---|
| **Birth weight-gestational age group** | **% Cases*** | **aRR (95% CI)†** | **PAF (95% CI)‡** | **Birth weight-gestational age group** | **% Cases** | **aRR (95% CI)** | **PAF (95% CI)** |
| CP | | | | CP | | | |
| VLBW-Preterm§ | 32.7 | **43.5 (24.4, 77.6)** | **32.0 (20.3, 46.2)** | VLBW-Preterm | 32.7 | **43.5 (24.4, 77.6)** | **32.0 (20.3, 46.2)** |
| MLBW-Preterm | 20.7 | **10.1 (5.0, 20.7)** | **18.7 (8.7, 33.6)** | MLBW-Preterm | 20.7 | **10.1 (5.0, 20.7)** | **18.7 (8.7, 33.6)** |
| MLBW-Term | 2.9 | 1.7 (0.7, 4.4) | 1.2 (0.0, 5.9) | MLBW-Term | 2.9 | 1.7 (0.7, 4.4) | 1.2 (0.0, 5.9) |
| NBW-Preterm | 5.4 | **2.2 (1.04, 4.6)** | 2.9 (0.0, 8.8) | NBW-Preterm | 5.4 | **2.2 (1.04, 4.6)** | 2.9 (0.0, 8.8) |
| NBW-Term | 38.3 | 1.0 | 0.0 | NBW-Term | 38.3 | 1.0 | 0.0 |
| Summary PAF | — | — | **54.8 (38.3, 68.9)** | Summary PAF | — | — | **54.8 (38.3, 68.9)** |
| ASD | | | | ASD (no CP) | | | |
| VLBW-Preterm | 4.2 | **3.7 (1.8, 7.7)** | **3.1 (0.7, 8.8)** | VLBW-Preterm | 3.9 | **3.6 (1.6, 7.9)** | **2.8 (0.5, 8.8)** |
| MLBW-Preterm | 6.8 | **1.9 (1.3, 2.7)** | **3.1 (0.8, 6.5)** | MLBW-Preterm | 6.7 | **1.9 (1.3, 2.7)** | **3.1 (0.8, 6.5)** |
| MLBW-Term | 2.7 | 1.2 (0.6, 2.1) | 0.4 (0.0, 3.0) | MLBW-Term | 2.7 | 1.2 (0.6, 2.2) | 0.4 (0.0, 3.0) |
| NBW-Preterm | 10.7 | **2.0 (1.3, 3.0)** | **5.3 (1.3, 11.2)** | NBW-Preterm | 10.6 | **2.0 (1.3, 3.0)** | **5.3 (1.2, 11.2)** |
| NBW-Term | 75.7 | 1.0 | 0.0 | NBW-Term | 76.1 | 1.0 | 0.0 |
| Summary PAF | — | — | **11.9 (5.6, 19.4)** | Summary PAF | — | — | **11.6 (5.3, 19.2)** |
| ID | | | | ID (no CP, ASD) | | | |
| VLBW-Preterm | 6.6 | **5.1 (2.6, 10.0)** | **5.3 (1.7, 13.0)** | VLBW-Preterm | 3.3 | **2.6 (1.1, 6.1)** | **2.0 (0.0, 6.7)** |
| MLBW-Preterm | 9.6 | **2.7 (1.8, 4.2)** | **6.1 (2.5, 11.3)** | MLBW-Preterm | 8.9 | **2.4 (1.4, 4.2)** | **5.2 (1.0, 12.2)** |
| MLBW-Term | 4.6 | 1.7 (0.9, 2.9) | 1.8 (0.0, 5.7) | MLBW-Term | 5.0 | 1.7 (0.9, 3.1) | 2.0 (0.0, 6.6) |
| NBW-Preterm | 10.0 | **2.2 (1.5, 3.2)** | **5.4 (1.9, 10.1)** | NBW-Preterm | 8.8 | **1.9 (1.2, 3.0)** | **4.0 (0.4, 9.5)** |
| NBW-Term | 69.2 | 1.0 | 0.0 | NBW-Term | 74.0 | 1.0 | 0.0 |
| Summary PAF | — | — | **18.6 (10.6, 27.8)** | Summary PAF | — | — | **13.2 (4.9, 23.4)** |
| BCD | | | | BCD (no CP, ASD, ID) | | | |
| VLBW-Preterm | 1.8 | 1.1 (0.6, 2.0) | 0.2 (0.0, 1.8) | VLBW-Preterm | 1.8 | 1.2 (0.6, 2.6) | 0.3 (0.0, 2.6) |
| MLBW-Preterm | 6.3 | **1.5 (1.1, 2.1)** | **2.1 (0.1, 4.8)** | MLBW-Preterm | 6.5 | **1.6 (1.1, 2.2)** | **2.3 (0.1, 5.5)** |
| MLBW-Term | 3.4 | 1.0 (0.7, 1.6) | 0.1 (0.0, 2.2) | MLBW-Term | 3.8 | 1.1 (0.7, 1.8) | 0.4 (0.0, 3.1) |

| Assessment of DDs without consideration of co-occurrence | | | | Assessment of DDs in mutually exclusive categories. | | | |
|---|---|---|---|---|---|---|---|
| **Birth weight-gestational age group** | **% Cases*** | **aRR (95% CI)†** | **PAF (95% CI)‡** | **Birth weight-gestational age group** | **% Cases** | **aRR (95% CI)** | **PAF (95% CI)** |
| NBW-Preterm | 7.4 | 1.4 (0.99, 1.9) | 1.9 (0.0, 5.0) | NBW-Preterm | 7.2 | 1.4 (0.9, 2.0) | 1.9 (0.0, 5.8) |
| NBW-Term | 81.2 | 1.0 | 0.0 | NBW-Term | 80.8 | 1.0 | 0.0 |
| Summary PAF | — | — | **4.3 (0.3, 9.0)** | Summary PAF | — | — | **5.0 (0.3, 10.5)** |
| ADHD | | | | ADHD (no CP, ASD, ID, BCD) | | | |
| VLBW-Preterm | 2.2 | **1.6 (1.2, 2.3)** | 0.9 (0.2, 1.9) | VLBW-Preterm | 1.6 | 1.3 (0.9, 2.0) | 0.4 (0.0, 1.3) |
| MLBW-Preterm | 5.0 | **1.3 (1.04, 1.5)** | 1.1 (0.1, 2.3) | MLBW-Preterm | 4.7 | 1.3 (0.99, 1.6) | 1.0 (0.0, 2.5) |
| MLBW-Term | 2.8 | 1.0 (0.8, 1.3) | 0.0 (0.0, 1.0) | MLBW-Term | 2.6 | 0.9 (0.7, 1.3) | 0.0 (0.0, 1.1) |
| NBW-Preterm | 8.2 | **1.5 (1.2, 1.8)** | **2.5 (1.0, 4.5)** | NBW-Preterm | 8.1 | **1.5 (1.2, 1.9)** | **2.6 (0.6, 5.1)** |
| NBW-Term | 81.8 | 1.0 | 0.0 | NBW-Term | 83.0 | 1.0 | 0.0 |
| Summary PAF | — | — | **4.4 (2.0, 7.1)** | Summary PAF | — | — | **3.8 (1.0, 7.06)** |
| LD | | | | LD (no CP, ASD, ID, BCD, ADHD) | | | |
| VLBW-Preterm | 3.7 | **2.8 (2.1, 3.7)** | **2.4 (1.3, 3.8)** | VLBW-Preterm | 4.2 | **3.3 (2.0, 5.4)** | **3.0 (1.2, 5.9)** |
| MLBW-Preterm | 7.8 | **2.0 (1.7, 2.4)** | **3.9 (2.4, 5.7)** | MLBW-Preterm | 7.1 | **2.0 (1.3, 2.8)** | **3.5 (1.0, 7.0)** |
| MLBW-Term | 3.6 | 1.2 (0.9, 1.6) | 0.7 (0.0, 2.0) | MLBW-Term | 4.2 | 1.3 (0.8, 2.0) | 1.0 (0.0, 3.8) |
| NBW-Preterm | 8.3 | **1.6 (1.4, 2.0)** | **3.2 (1.6, 5.2)** | NBW-Preterm | 6.5 | 1.4 (1.00, 1.9) | 1.7 (0.0, 4.4) |
| NBW-Term | 76.5 | 1.0 | 0.0 | NBW-Term | 77.9 | 1.0 | 0.0 |
| Summary PAF | — | — | **10.2 (7.3, 13.4)** | Summary PAF | — | — | **9.1 (4.4, 14.5)** |
| Other developmental delay | | | | Other developmental delay (no CP, ASD, ID, BCD, ADHD, LD) | | | |
| VLBW-Preterm | 6.8 | **5.5 (4.1, 7.4)** | **5.6 (3.6, 8.2)** | VLBW-Preterm | 8.8 | **9.8 (5.0, 19.2)** | **7.9 (3.6, 15.4)** |
| MLBW-Preterm | 10.1 | **2.8 (2.2, 3.6)** | **6.5 (4.0, 9.6)** | MLBW-Preterm | 9.0 | **2.7 (1.4, 5.1)** | **5.6 (1.0, 14.0)** |
| MLBW-Term | 3.5 | 1.4 (0.9, 2.0) | 1.0 (0.0, 2.9) | MLBW-Term | 2.6 | 1.1 (0.4, 3.5) | 0.3 (0.0, 6.2) |
| NBW-Preterm | 10.7 | **2.3 (1.8, 3.0)** | **6.1 (3.2, 9.8)** | NBW-Preterm | 12.9 | **3.0 (1.6, 5.6)** | **8.6 (2.2, 19.5)** |
| NBW-Term | 68.8 | 1.0 | 0.0 | NBW-Term | 66.8 | 1.0 | 0.0 |
| Summary PAF | — | — | **19.1 (14.2, 24.2)** | Summary PAF | — | — | **22.4 (10.9, 36.0)** |

*% cases: (number of exposed cases/number of all cases) × 100, weighted.

†aRR: Relative risk, adjusted for child age, sex, race/ethnicity, maternal education, and maternal age. Findings in boldface indicate 95% confidence interval excludes 1.0.

‡PAF estimate or lower bound of PAF CI reported as 0.0 for all instances in which the value was less than 0.0. Findings in boldface indicate 95% confidence interval excludes 0.0.

§All VLBW births were preterm. We excluded from our study sample a small number of children classified as both VLBW and Term. These data were considered implausible as birth weights less than 1500 g are below the third percentile of what is expected for births at 37 weeks' gestation or higher based on a US national reference for both males and females.

## Table 4

Summary population attributable fractions for impact of preterm and low birth weight on developmental disabilities among subgroups based on parent-reported disability severity level and child race-ethnicity: children 3–17 years of age, 2011–2012 National Survey of Children's Health

| DD type (without consideration of DD co-occurrence) | Severity reported as mild PAF (95% CI)* | Severity reported as moderate or severe PAF (95% CI) | Non-Hispanic white PAF (95% CI)* | Non-Hispanic black PAF (95% CI) |
|---|---|---|---|---|
| CP | **48.0 (26.4, 68.0)** | **62.7 (39.4, 80.1)** | **46.1 (28.2, 63.2)** | **68.5 (27.5, 90.6)** |
| ASD | 5.2 (0.0, 13.0) | **19.5 (8.7, 32.8)** | **6.8 (1.3, 13.6)** | 16.5 (0.0, 43.5) |
| ID | 6.9 (0.0, 22.2) | **17.7 (6.6, 31.4)** | **16.3 (8.2, 26.0)** | **17.8 (2.0, 39.0)** |
| BCD | 5.5 (0.0, 17.1) | 4.7 (0.0, 11.0) | 4.1 (0.0, 10.9) | **11.9 (0.7, 26.0)** |
| ADHD | 3.0 (0.0, 7.1) | **4.9 (0.3, 10.4)** | **3.6 (0.9, 6.7)** | **10.0 (2.0, 19.5)** |
| LD | 5.3 (0.5, 11.3) | **16.2 (7.1, 27.0)** | **8.0 (4.9, 11.6)** | **15.9 (7.9, 25.2)** |
| Other developmental delay | **21.0 (8.9, 35.9)** | **28.0 (3.2, 57.7)** | **15.9 (10.6, 21.7)** | **23.1 (10.3, 37.6)** |

*PAF estimate or lower bound of PAF CI reported as 0.0 for all instances in which the value was less than 0.0. Findings in boldface indicate 95% confidence interval excludes 0.0.