Risk of Developmental Disorders in Children Born at 32 to 38 Weeks' Gestation: A Meta-Analysis

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abstract

CONTEXT: Very preterm birth (<32 weeks) is associated with increased risk of developmental disorders. Emerging evidence suggests children born 32 to 38 weeks might also be at risk.

OBJECTIVES: To determine the relative risk and prevalence of being diagnosed with, or screening positive for, developmental disorders in children born moderately preterm, late preterm, and early term compared with term (≥37 weeks) or full term (39–40/41 weeks).

DATA SOURCES: Medline, Embase, Psychinfo, Cumulative Index of Nursing, and Allied Health Literature.

STUDY SELECTION: Reported ≥1 developmental disorder, provided estimates for children born 32 to 38 weeks.

DATA EXTRACTION: A single reviewer extracted data; a 20% sample was second checked. Data were pooled using random-effects meta-analyses.

RESULTS: Seventy six studies were included. Compared with term born children, there was increased risk of most developmental disorders, particularly in the moderately preterm group, but also in late preterm and early term groups: the relative risk of cerebral palsy was, for 32 to 33 weeks: 14.1 (95% confidence intervals [CI]: 12.3–16.0), 34 to 36 weeks: 3.52 (95% CI: 3.16–3.92) and 37 to 38 weeks: 1.44 (95% CI: 1.32–1.58).

LIMITATIONS: Studies assessed children at different ages using varied criteria. The majority were from economically developed countries. All were published in English. Data were variably sparse; subgroup comparisons were sometimes based on single studies.

CONCLUSIONS: Children born moderately preterm are at increased risk of being diagnosed with or screening positive for developmental disorders compared with term born children. This association is also demonstrated in late preterm and early term groups but effect sizes are smaller.

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Dr Pettinger conceptualized and designed the study, performed the literature search, data extraction and data analysis, drafted the initial manuscript, and revised the manuscript; Mrs Copper participated in the literature search and data extraction and critically reviewed the manuscript; Drs Blower, Boyle, Hewitt, and Fraser supervised the study design, the literature search, data extraction and analysis, and critically reviewed and revised the manuscript; and all authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

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Preterm birth (<37 weeks) is associated with increased risk of developmental disorders, defined as: "heterogeneous conditions that share a disturbance in the acquisition of basic developmental skills in a chronologically appropriate manner."[1]

Most literature focuses on outcomes of children born very (<32 weeks), or extremely preterm (<28 weeks).[2,3] However these represent only 15% of preterm births globally.[4] Emerging evidence suggests early term birth (37–38 weeks) may also affect development.[5,6]

The aim of this review was to determine the relative risk and prevalence of developmental disorders in children born between 32 and 38 weeks' gestation, compared with term born children. Although previous reviews have explored some aspects of this question,[7–10] to our knowledge there are no meta-analyses that have explored outcomes for moderately preterm, late preterm, and early term children and considered all developmental disorders.

Understanding the epidemiology of developmental disorders among children born between 32 and 38 weeks is important, not least because birth at this stage is common: in the United States in 2020, 27.8% of births were early term, 7.4% late preterm (34–36 weeks), and 1.2% moderately preterm (32–33 weeks) (compared with 0.6% extremely preterm).[11] Knowing which disorders are most prevalent among these children could improve targeting of resources and antenatal counseling and potentially avoid delayed diagnosis and missed opportunities for intervention.[12–15]

METHODS

Search Strategy and Selection Criteria

This systematic review was registered with PROSPERO (CRD42021298773) and reported according to PRISMA guidelines.[16] The population of interest was children born between 32 and 38 weeks, aged 2 to 17 years at assessment, born after 1996, when antenatal steroids administration in preterm labor became routine practice.[17] Comparator groups were (where possible) children born at full term (39–40/41 weeks), or if this data were not presented, at term (≥37 weeks) . The outcomes were developmental disorders as per the National Institute for Health and Care Excellence,[18] which in some cases were subdivided further to allow meaningful comparison: cerebral palsy (CP); developmental coordination disorder (DCD); visual impairment; hearing impairment; sleep apnea; oro-motor feeding problems; social, emotional, and behavioral problems subdivided into: global social, emotional, and behavioral problems, internalizing behaviors, externalizing behaviors, and social problems; attention deficit hyperactivity disorder (ADHD); autism spectrum disorder (ASD); developmental delay subdivided into: global developmental delay, language delay, motor developmental delay, and cognitive developmental delay; cognitive impairment; executive function problems; low educational achievement, subdivided into: not "school ready" aged ≤5 years, low educational achievement aged 6 to 11 years, and low educational achievement aged 12 to 17 years; and special educational needs (including physical disabilities which affect learning as well as learning impairments).[19]

Searches were conducted in Medline, Embase, Psychinfo, Cumulative Index of Nursing and Allied Health Literature on February 10, 2022 (updated November 22, 2022). The search terms are listed in Supplemental Table 4. In addition, a Google scholar search was conducted on February 14, 2022. Initially the advanced search feature of Google Scholar was used, but the resulting studies were not relevant. Therefore, a basic search was performed using the question: "What is the risk of neurodevelopmental disorder in children born between 32 and 38 weeks gestation?". The top 50 results were exported. Reference lists of included studies were searched for additional studies that met the inclusion criteria, as follows: at least 1 developmental disorder identified on a validated questionnaire, standardized test, or physician diagnosis; provided estimates for children born moderately or late preterm, or early term.

One author (K.P.) reviewed all titles, abstracts, and full texts using Covidence software.[20] Twenty percent were independently reviewed by a second author (C.C.). There was substantial agreement; 93.6% and Cohen's κ 0.62 at abstract screening; 98.4% and Cohen's κ 0.85 at full text review.[21] Disagreements were resolved by discussion.

Where key data were missing, authors were contacted by e-mail; if no response was received, the study was excluded. Where studies used the same cohort, the most recent publication was included, unless an older study provided the results in a binary format, enabling prevalence calculation (Supplemental Table 5 for summary). The full list of exclusion criteria can be found in the study protocol (CRD42021298773).

Data Extraction

Data were extracted by K.P. and a 20% sample was cross-checked by C.C. for accuracy. See Supplemental Table 3 for data extraction form. Where only odds ratios were presented, the study authors were contacted to request the raw data.

Study Quality

The Newcastle-Ottawa scale was used to assess quality with scores categorized as poor (0–2), fair (3–5), or good (6–9) (Supplemental Fig 11).[22]

Data Analysis

An unadjusted pooled relative risk of each outcome by gestational age was calculated using random effects meta-analysis because of expected heterogeneity, quantified using the I^2 statistic. The number of children with each disorder, the number

without, and the total number of participants (split into gestational subgroups) was used in the calculations. If raw numbers were not presented (or supplied on request), the paper's unadjusted calculated effect sizes (relative risk) were used. When there were 0 cases, a continuity correction of 0.5 was applied. For continuous measures, studies were pooled using Hedge's G standardized mean difference. Signs were changed where necessary.[23] Prevalence was pooled by gestational age with a fixed effect model using the inverse-variance method. The Freeman Tukey double arcsine transformation was specified where necessary to stabilize variances.[24,25] Publication bias was assessed using Egger's test and funnel plots.

Analyses were undertaken by gestational age groupings: moderately preterm (32–33 weeks); late preterm (34–36 weeks); early term (37–38 weeks)[5,26,27]; moderate-to-late preterm (32–36 weeks), but only if results were presented in this format without further breakdown.

Where results were not presented as above, broader groupings were used: 32 weeks was coded as 32–33 weeks; 35–36 weeks was coded as 34–36 weeks; 33–36 weeks, 32–34 weeks, 32–35 weeks, or 32–37 weeks were all coded as 32–36 weeks; and 32–34 weeks and 35–36 weeks were combined into 32–36 weeks.

Where data were available for children born at 32–33 weeks and 34–36 weeks, the 32–36 week category was not presented.

Sensitivity Analysis

Sensitivity analysis was undertaken for relative risk of CP, global developmental delay, and educational outcomes aged 6 to 11 years by comparing results when studies using a ≥37 week term comparison group (as opposed to a 39–40/41 weeks comparison group) were included and excluded.

RESULTS

The initial search identified 11 630 records with 17 further studies from reference screening and updated searches. As shown in Fig 1, 9028 studies were excluded at the first stage and 1462 studies were full text screened; 1386 were excluded, resulting in 76 studies included. There was full agreement between the 2 researchers conducting data extraction.

Study Characteristics

Key characteristics of the included studies are summarized in Table 1. Several studies reported multiple outcomes. All were cohort or cross sectional studies. Sample sizes ranged from 83 to 1 390 601 and covered the full age

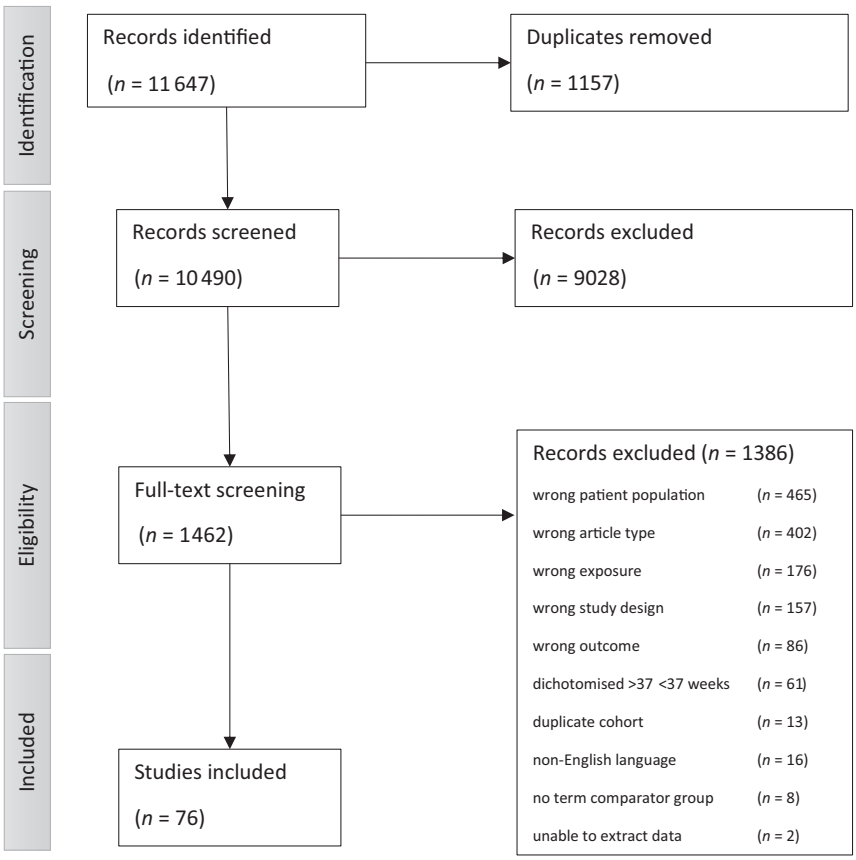

FIGURE 1
Study selection process.

TABLE 1 Key Characteristics of Included Studies Organized by Country, Then by Year of Publication

Record ID	Participants' Country of Origin	Total Participants Included in Meta-analysis	Age at Assessment	Birth Year of Participants	% Male (whole cohort unless ≥1% difference in gestational age groups)	Ethnicity of Participants Using Same Terminology as the Studies (whole cohort or term group)	Developmental Disorders Reported	Study Quality
Baron 2009[53]	United States	34–36 wk: 60; ≥37 wk: 35	3 y	2004–2005	34–36 wk 45%; ≥37 wk 60%	NR	Cognition	Fair
Morse 2009[54]	United States	34–36 wk: 7152; ≥37 wk: 152 661 (SEN)	4 y	1996–1997	34–36 wk: 52.2%; ≥37 wk: 51.3%	Black 21.32%; white 55.69%; other 22.98%	SEN, education - not school ready	Good
Petrini 2009[55]	United States	34–36 wk: 8341; 37–41weeks: 128 955 (CP)	1–5 y	2000–2004	34–36 wk: 54.4%; 37–41 wk: 50.9%	Hispanic 24.5%; Asian 18.2%; white 41.5%; unknown 8.5%; Black 7.3%	CP, DD	Good
Baron 2010[56]	United States	35–36 wk: 118; ≥37 wk: 100	3 y	2004–2006	35–36 wk: 50%; ≥37 wk: 60%	Caucasian 72% multiracial 14%; Hispanic: 6%, Asian 4%; African/African American 3%; other 1%	Cognition	Good
Woythaler 2011[57]	United States	34–36 wk: 1200; ≥37 wk: 6300	2 y	2001	34–36 wk: 52.6%; ≥37 wk: 51.4%	White 81.4%; Black 14.3%; other 4.3%	DD	Good
Baron 2012[58]	United States	34–36 wk: 52; ≥37 wk: 195	3 y	2004 and 2006	34–36 wk: 51%; ≥37 wk: 59%	Caucasian 72.7%	Cognition	Fair
Curry 2012[59]	United States	32–33 wk: 3973; 34–36 wk: 21 835; 37–38 wk: 79 228; ≥39 wk: 229 626	Up to 3 y	1999–2001	51.3% (NR by gestation)	Hispanic 34.3%, Asian/Pacific Islander 11.9%, Black, non-Hispanic 27.6%, white, non-Hispanic 25.9%, other 0.2%	DD	Good
Talge 2012[60]	United States	3–5 y: 34–36 wk: 96; ≥37 wk: 388; 6–9 y: 34–36 wk: 56; ≥37 wk: 222	3–5 y and 6–9 y	1998–2004	48%	White or other 76%; African American 24%	SEB, ADHD	Good
Baron 2014[61]	United States	34–36 wk: 410; ≥37 wk: 192	3 y	2004–2008	34–36 wk: 55.4%; ≥37 wk: 53.1%	White 67.7%; other 24%; Hispanic 6.3%; African American: 2.1%	Cognition	Good
Brumbaugh 2014[62]	United States	32–34 wk: 39; 38–42 wk: 44; (cognition)	4 y	2005–2006	32–34 wk:59%; 38–42 wk: 50%	NR	Executive function, cognition	Fair
Kuzniewicz 2014[63]	United States	34–36 wk: 11 945; ≥37 wk: 177 129	Minimum 2 y	2000–2007	NR	White: 42%; Hispanic: 24%; Asian: 21%; Black 7%; other 6%	ASD	Good
Richards 2015[64]	United States	34–36 wk: 25 850; 37–41 wk: 29 4076	6–8 y	1998–2002	34–36 wk: 52.9%; 37–41 wk: 50.4%	White non-Hispanic 55.6%; Black non-Hispanic 34.4%; Hispanic 10.0%	Education–aged 6–11 y	Good
Woythaler 2015[65]	United States	34–36 wk: 950; ≥37 wk: 4900	5 y	2001	34–36 wk: 53.6%, ≥37 wk: 50.4%	White 81.1%; Black: 14.6%; other: 4.3%	Education- not school ready	Good
Hodel 2016[66]	United States	32–36 wk: 45; 37–42 wk: 44; (cognition)	4.5 y	Not stated	32–36 wk: 51.1%; 37–42 wk: 54.3%	Caucasian 92%	Cognition, executive function	Fair
Crockett 2022[67]	United States	34–36 wk: 1339; 39–41 wk: 15 203	Up to age 8	2000–2005	34–36 wk: 53.6%; 39–41 wk: 51.1%	NR	Education- not school ready and aged 6–11 y, ADHD	Good

TABLE 1 Continued

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Lingasubramanian 2022[68]	United States	37–38 wk: 400; 39–41 wk: 1022	9 y	1998–2000	52%	Non-Hispanic white 22%; Non-Hispanic Black 48%; Hispanic 27%; another non-white 4%	ADHD	Good
Wehby 2022[69]	United States	32–36 wk: 75 017; ≥37 wk: 888 623	6–16 y	2002–2010	51%	White 94%; Black 3%; other3%	Education	Good
Robaei 2006[70]	Australia	32–36 wk: 115; ≥37 wk: 1343 (vision)	6 y	1997–1998	32–36 wk: 52%; ≥37 wk: 51%	White 65.9%; Southeast Asian 15.5%; other 18.5%	Vision	Fair
Raynes-Greenow 2012[71]	Australia	32–36 wk: 22 039; ≥37 wk: 377 952	2–6 y	2000–2004	51.4%	NR	Sleep apnea	Good
Schneider 2014[72]	Australia	33–36 wk: 63; 37–41 wk: 44	12 y (mean)	1996–1997	33–36 wk: 57%; 37–41 wk: 52%	NR	Cognition	Good
Smithers 2015[73]	Australia	37–38 wk: 3374; 39–40 wk: 7505	5 y (median)	2004	Whole cohort 50%; (NR by gestation)	Aboriginal and/or Torres Strait Islander 3.3%	Education- not school ready	Good
Cheong 2017[28]	Australia	32–36 wk: 176; ≥37 wk: 150; (SEB - social)	2 y	2009–2012	32–36 wk: 47.8%; ≥37 wk: 53.2%	NR	DD, SEB, CP	Good
Searle 2017[74]	Australia	32–36 wk: 838; 37–38 wk: 3762; 40 wk: 6224	8 y	2000–2002	50.2% (NR by gestation)	NR	Education–aged 6–11 y	Good
Hanly 2018[46]	Australia	34–36 wk: 3932; 37–38 wk: 20 951; 39–40 wk: 43 199	5 y	2004–2007	Whole cohort 50.7% (NR by gestation)	Aboriginal 7%	Education- not school ready	Good
Brown 2019[75]	Australia	34–36 wk: 76; 37–38 wk: 295; 39–40 wk: 471	8–9 y	2005–2006	52.0% (NR by gestation)	NR	Education– aged 6–11years	Good
Dhamrait 2021[76]	Australia	32–36 wk: 3709; ≥37 wk: 60 675	4–5 y	2004	32–36 wk 52.8%; 37–38 wk 50.8%; 39–40 wk 49.4%	Caucasian 82%; other 12.3%; Indigenous Australian 5.7%	Education- not school ready	Good
Poulsen 2013[77]	UK	32–33 wk: 123; 34–36 wk: 646; 37–38 wk: 2188; 39–41 wk: 8096 (cognition)	3 y	2000–2002	32–33 wk: 59.7%; 39–41 wk: 50.6%	White British: 80% to 89%	Education- not school ready, cognition	Good
Guy 2015[78]	UK	32–33 wk: 82; 34–36 wk: 539; ≥ 37 wk: 749	2 y	2009–2010	NR	98% White in the group with a negative ASD screen	ASD	Fair
Johnson 2015a[3]	UK	32–33 wk: 85; 34–36 wk: 545; 37–42 wk: 750	2 y	2009–2010	32–36 wk: 53.8%; term: 50.2%	White 82.5%, Asian or Asian British 11.2%, Black or Black British 4.4%, Chinese or other 1.0%, Mixed 1.0%	DD	Good
Johnson 2015b[79]	UK	32–33 wk: 84; 34–36 wk: 541; ≥37 wk: 760	2 y	2009–2010	32–36 wk: 53.8%; term: 50.2%	White 78.6%; Asian or Asian British 4.7%; Black or Black British 3.6% Mixed 2.0%; Chinese or other 1.0%; unknown 0.2%	SEB	Good
Cronin 2016[80]	UK	32–33 wk: 164; 34–36 wk: 691; 37–38 wk: 2864; 39–41 wk: 9811	5 y	2002	32–33 wk: 57.3%; 34–36 wk: 53.7%; 37–38 wk: 51.9%; 37–41 wk: 50.6%	White British 87.9%	SEB	Good

TABLE 1 Continued

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Pettinger 2020[81]	UK	32–33 wk: 65; 34–36 wk: 478; 37–38 wk: 2355; 39–41 wk: 7269	4 y	2007–2010	52%	English as additional language: 45%	Education - not school ready	Good
Alterman 2021[82]	UK	32–33 wk: 135; 34–36 wk: 732; 37–38 wk: 2460; 39–40 wk 6051	11 y	2000–2002	Whole cohort: 51%; 34–36 wk: 64%	White 87.1%, other 12.9%	SEN	Good
Alterman 2022[83]	UK	32–33 wk: 76; 34–36 wk: 401; 37–38 wk: 1408; 39–41 wk: 4896 (education aged 6–11 y)	11 y	2000–2001	32–33 wk: 63.6%; 34–36 wk: 51.4%; 37–38 wk: 52.5%; 39–41 wk: 49.8%	White: 85.2%	Education aged 6–11 y, education aged 12–17 y	Good
Libuy 2022[84]	UK	32–33 wk: 2227; 34–36 wk: 13 385; 37–38 wk: 57 955; 39–40 wk: 156 376	11 y	2004–2005	32–33 wk: 55.1%; 34–36 wk: 54.6%; 37–38 wk: 52.2%; 39–40 wk: 50.5%	White: 78.6%, Asian 10.1%; Black 5.0%, any other ethnic group 1.4%, mixed 4.9%	SEN, education aged 6–11 y	Good
Van Baar 2009[85]	The Netherlands	32–36 wk: 377; ≥37 wk: 182	8 y	1996–1999	32–36 wk: 52%; ≥37 wk: 47%	Dutch 91%	Cognition, SEB	Good
Bul 2012[86]	The Netherlands	32–36 wk: 348; ≥37 wk: 182	8 y	1996–1999	32–36 wk: 51.1%, ≥37 wk: 47.8%	NR	SEB, ADHD	Good
Cserjesi 2012[87]	The Netherlands	32–36 wk: 248; 38–41 wk: 130	6.9 y (mean)	2002–2003	32–36 wk: 55.6%; 38–41 wk: 44.6%	NR	Cognition	Good
de Jong 2015[88]	The Netherlands	32–36 wk: 116; 37–41 wk: 98; (cognition)	4 y	2010–2011	32–36 wk 57.8%; >37 wk: 45.5%	Dutch 95.9%	Cognition, DD, SEB	Fair
Potijk 2015[89]	The Netherlands	32–36 wk: 915; ≥37 wk: 543	3 y	2002–2003	54.2%	Dutch: 94.6%	SEB	Good
Hornman 2017[90]	The Netherlands	32–36 wk: 644; 38–41 wk: 375	4 y	2002–2003	34–36 wk: 58.3%; 38–41 wk: 47.1%	Non-Dutch background 4.3%	DD	Good
Hua 2021[91]	China	32–33 wk: 2322; 34–36 wk: 12 915; 37–38 wk: 38 875; 39–40 wk: 76 501	3–5 y	2013–2016	32–33 wk: 54.0%; 34–36 wk: 55.3%; 37–38 wk: 55.3%; 39–40 wk: 51.6%	Han Chinese 99%	Motor	Good
You 2019a[92]	China	34–36 wk: 102; 37–42 wk: 153	24–30 mo	2011–2013	34–36 wk: 66.7%; 37–42 wk: 61.4%	NR	DD, CP	Good
You 2019b[93]	China	34–36 wk: 112; 37–42 wk: 179	2 y	2013–2015	34–36 wk: 54.5%; 37–42 wk: 47.5%	NR	DD, CP	Fair
Zhou 2020[45]	China	32–37 wk: 83; 37–42 wk:1665	1 mo–5 y	2011–2016	32–37 wk: 51.8%; 37–42 wk: 53.8%	NR	DD	Good
Stene-Larsen 2014[94]	Norway	34–36 wk: 1673; 37–38 wk: 7109; 39–41 wk: 30 641	3 y	1999–2008	34–36 wk: 51.3%; 37–38 wk: 48.6%; 39–41 wk: 50.4%	NR	DD	Good
Strand 2013[95]	Norway	32–36 wk: 23 763; 37–40 wk: 522 551	4 y (minimum)	1996–2006	NR - only reported for pre-eclampsia versus no pre-eclampsia	NR	CP	Good
Ask 2018[96]	Norway	34–36 wk: 1755; 37–38 wk: 6732; 40 wk: 11 753 (SEB)	5 y	1999–2008	Whole cohort 51.3% (NR by gestation)	NR	SEB, ADHD	Good
Zambrana 2021[97]	Norway	Total: 26 769	3 y	1999–2008	51.5% (NR by gestation)	NR	DD	Good
Demestre 2016[98]	Spain	34–36 wk: 90; 38–41 wk: 89	4 y	2009	34–36 wk: 61%; 38–41 wk: 55%	NR	DD	Good

TABLE 1 Continued

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Oros 2014[99]	Spain	34–36 wk: 6; ≥37 wk: 96	6–13 y	1997–2005	34–36 wk: 40.9%; term 52.6%	Caucasian 99.3%	Cognition	Fair
Pérez-Pereira 2014[100]	Spain	34–36 wk: 47; ≥37 wk: 36	2.5 y	Unclear	34–36 wk: 56.5%; ≥37 wk: 51.4%	NR	Speech	Fair
Pérez-Pereira 2020[101]	Spain	32–33 wk: 31; 34–36 wk: 42; ≥37 wk: 33	5 y	Unclear	52%	NR	Cognition	Good
Klassen 2004[102]	Canada	33–37 wk: 341; >37 wk: 259 (vision)	3.5 y	1996–1997	33–37 wk: 45.2%; >37 wk: 40.2%	NR	DD, hearing, vision	Fair
Leavey 2013[103]	Canada	32–33 wk: 2373; 34–36 wk: 13 108; 37–38 wk: 51 307; 39–41 wk: 146 467	Minimum 3 y	1998–2004	49%	NR	ASD	Good
Faleschini 2020[104]	Canada	32–36 wk: 89; ≥37 wk: 1841	4 y	1997–1998	32–36 wk: 52%; ≥37 wk: 50%	Born in Canada 87%	SEB, ADHD	Good
Chen 2020[105]	Sweden	37–38 wk: 132 997; 39–41 wk: 530 988	3 y	1998–2009	51.1%	NR	Cognition	Good
Beer 2022[106]	Sweden	32–36 wk: 47 859; 37–41 wk: 1 071 729	3–15 y	2002–2014	NR	NR	ADHD	Good
Chen 2022[107]	Sweden	32–36 wk: 77 986; 37–38 wk: 346 859; 39–40 wk: 965 756	0–16 y (median 9.4 y)	1998–2016	50.4% (NR by gestation)	NR	CP	Good
Larsen 2021[108]	Denmark	32–33 wk: 6067; 34–36 wk: 29 821; 37–41 wk: 531 996 (SEN)	4–6 y	1997–2013	NR - it is only reported for each disorder not each gestation	NR	SEN, CP	Good
Zhu 2012[109]	Denmark	32–33 wk: 123; 34–36 wk: 721; 37–38 wk: 3519; 39–40 wk: 11 743	7 y	1996–2002	51%	NR	Motor	Good
Larroque 2008[110]	France	32 wk: 484; 39–40 wk: 389 (vision)	5 y	1997	52% male	NR	Cognition, hearing, vision, CP	Good
Bailhache 2022[111]	France	32–36 wk: 421; ≥37 wk: 4164	9 y	2011	50.9%	NR	SEB, ADHD	Good
Voigt 2012[112]	Germany	32–37 wk: 88; ≥38 wk: 86	2 y	2007–2008	32–37 wk 51%; ≥38 wk 47%	NR	Cognition, SEB, ADHD	Fair
Reuner 2015[113]	Germany	33–36 wk 54; ≥37 wk 38	2 y	2008–2009	33–36 wk: 50%; ≥37 wk: 47%	NR	Cognition	Fair
Darlow 2009[114]	New Zealand	33–36 wk: 112; ≥37 wk: 101	2 y	2001–2002	33–36 wk: 61%; term admissions 59%	Māori 5.9%	CP, DD	Good
Berry 2018[115]	New Zealand	33–36 wk: 19 089; 37–38 wk: 70 026; 39–40 wk:180 987 (vision)	6–11 y	1998–2000 and 2005–2015	51.4%	European 67%; Pacific Islander 12%; Māori 21%	SEN, education aged 12–17 y, hearing, vision	Good
Yang 2010[116]	Belarus	38 wk: 2100; 39–41 wk: 11 074	6 y	1996–1997	38 wk: 53.8%; 39 wk: 50.8%; 40 wk: 51.7%	NR	Cognition	Good
Polic 2017[117]	Croatia	34–36 wk: 126; 37–40 wk: 131	6–12 y	2002–2008	34–36 wk: 56.3%; 37–40 wk: 59.5%	NR	SEB	Good

TABLE 1 Continued

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Hirvonen 2015[118]	Finland	32–33 wk: 4862; 34–36 wk: 28 152; ≥37 wk: 671 988	7 y	1996–2008	32–33 wk: 54.9%; 34–36 wk: 54.2%; ≥37 wk: 50.8%	NR	CP	Good
Drougia 2007[119]	Greece	34–36 wk 594; ≥37 wk: 1719	Minimum 2 y	1997–2003	NR	NR	CP	Good
Tso 2022[120]	Hong Kong	33–36 wk: 22 811; 37–41 wk: 330 087	6–17 y, mean 11 y 7 mo	2004–2014	52%	NR	ADHD	Good
Patil 2014[121]	India	32–36 wk: 100; ≥37 wk: 100	4–6 y	unclear	Preterm 59%; term 61%	NR	DD	Fair
Marotta 2020[122]	Italy	34–36 wk: 53; ≥37 wk: 53	5–11 y (mean 8)	2002–2010	39.6%	NR	SEB	Fair
Higa Diez 2016[123]	Japan	34–36 wk: 645; 37–38 wk: 5103; 39–41 wk: 11752	8 y	2001	34–36 wk 60.1%; 37–38 wk 55.3%; 39–41 wk 49.7%	NR	SEB, ADHD	Good
Al-Haddad 2017[124]	Lebanon	32–36 wk: 51; ≥ 37 wk: 69	4.9 y (mean)	2006–2014	55%	NR	Vision	Fair

ASD, autism spectrum disorder; ADHD, attention deficit hyperactivity disorder; CP, cerebral palsy; DD, developmental disorder; NA, not applicable; NR, not recorded; SEB, social, emotional, and behavioral disorders; SEN, special educational needs.

range (2–17 years). The majority were from economically developed countries. There were 59 studies rated as "good" quality and 15 as "fair"' (Supplemental Table 7). Two studies were cross sectional, therefore 2 of the Newcastle Ottawa Scale questions did not apply and so were not classified as good, fair, or poor quality. Twenty four meta-analyses were conducted, summarized in Table 2. No papers reported oro-motor feeding problems.

The relative risk of screening positive for, or a diagnosis of, a developmental disorder compared with children born at term, was highest in the moderately preterm group; there was a statistically significant increased relative risk of CP, social problems, ASD, global DD, cognitive impairment, low educational attainment, and special educational needs (Figs 2–9). Forest plots for the remaining disorders are presented in the supplemental information (Supplemental Figs 12–37).

The relative risk of CP compared with children born at term was, for 32 to 33 weeks: 14.1 (95% confidence intervals [CI]: 12.3–16.0), 34 to 36 weeks: 3.52 (95% CI: 3.16–3.92) and 37 to 38 weeks: 1.44 (95% CI: 1.32–1.58). The prevalence of CP per 1000 children was, for 32 to 33 weeks: 17.1 (95% CI: 15.1–19.3), 34 to 36 weeks: 2.95 (95% CI: 2.53–3.39), 37 to 38 weeks: 2.05 (95% CI: 1.91–2.21), and ≥37 weeks: 0.53 (95% CI: 0.50–0.57).

The relative risk of global developmental delay compared with children born at term was, for 32 to 33 weeks: 2.89 (95% CI: 2.77–3.02), 34 to 36 weeks: 1.61 (95% CI: 1.25–2.08) and 37 to 38 weeks: 1.14 (95% CI: 1.12–1.16). The prevalence of global developmental delay per 1000 children was, for 32 to 33 weeks: 350 (95% CI: 335–365), 34 to 36 weeks: 132 (95% CI: 128–136), 37 to 38 weeks: 138 (95% CI: 136–140), and ≥37 weeks: 65.5 (95% CI: 64.7–66.3).

The relative risk of ADHD compared with children born at term was, for 32 to 36 weeks: 1.25 (95% CI: 1.14–1.38), 34 to 36 weeks: 1.62 (95% CI: 1.38–1.90), 37 to 38 weeks: 1.19 (95% CI: 1.00–1.42). The prevalence of ADHD per 1000 children was, for 32 to 36 weeks: 34.9 (95% CI: 33.6–36.3), 34 to 36 weeks: 75.7 (95% CI: 66.1–86.0), 37 to 38 weeks: 37.2 (95% CI: 32.4–42.8), and ≥37 weeks 26.6 (95% CI: 26.3–26.8).

The relative risk of low educational achievement aged 6 to 11 years compared with children born at term was, for 32 to 33 weeks: 1.96 (95% CI: 1.11–3.43), 34 to 36 weeks: 1.21 (95% CI: 1.10–1.32), and 37 to 38 weeks: 1.13 (95% CI: 1.08–1.19). The prevalence of low educational achievement aged 6–11 years per 1000 children was, for 32 to 33 weeks: 304 (95% CI: 285–324), 34 to 36 weeks: 199 (95% CI: 195–203), 37 to 38 weeks: 224 (95% CI: 221–227), and ≥37 weeks: 163 (95% CI: 162–164). A similar pattern is seen across the other developmental disorders, as shown in Supplemental Figs 12–39 (in the supplemental information) and in the prevalence summary bar charts (Fig 10).

Visual or hearing impairment were slightly more prevalent in some of the groups born before full term. The relative risk

TABLE 2 Summary

Developmental Disorder	32–33 wk	32–36 wk	34–36 wk	37–38 wk
CP relative risk	↑	[b]	↑	↑
CP prevalence	↑	[b]	↑	↑
DCD relative risk	↔	[a]	↑	↑
DCD prevalence	↑	[a]	↑	↑
Visual impairment relative risk	↔	↔	[a]	↑
Visual impairment prevalence	↔	↑	[a]	↑
Hearing impairment relative risk	↔	↔	[a]	↑
Hearing impairment prevalence	↓	↑	[a]	↑
Sleep apnea relative risk	[a]	↑	[a]	[a]
Sleep apnea prevalence	[a]	↑	[a]	[a]
SEB global relative risk	↔	[b]	↑	↔
SEB global prevalence	↔	[b]	↑	↔
SEB global (continuous)	[a]	↓	↔	[a]
SEB internalizing relative risk	[a]	↔	↔	[a]
SEB internalizing prevalence	[a]	↔	↑	[a]
SEB externalizing relative risk	[a]	↔	[a]	[a]
SEB externalizing prevalence	[a]	↔	[a]	[a]
SEB social relative risk	↑	[b]	↑	[a]
SEB social prevalence	↔	[b]	↑	[a]
ADHD relative risk	[a]	↑	↑	↑
ADHD prevalence	[a]	↑	↑	↑
ADHD (continuous)	[a]		↑	↔
ASD relative risk	↑	[a]	↑	↔
ASD prevalence		[a]	↑	↓
Global DD relative risk	↑	[b]	↑	↑
Global DD prevalence	↑	[b]	↑	↑
Language DD relative risk	[a]	↔	↔	↔
Language DD prevalence	[a]	↑	↑	↑
Motor DD relative risk	[a]	↔	↔	[a]
Motor DD prevalence	[a]	↑	↔	[a]
Cognitive DD relative risk	[a]	↑	↑	[a]
Cognitive DD prevalence	[a]	↔	↑	[a]
Cognitive impairment relative risk	↑	[a]	↔	↑
Cognitive impairment prevalence	↑	[a]	↑	↑
Cognitive impairment (continuous)	↔	[b]	↑	↑
Executive function (continuous)	[a]	↔	↔	[a]
Not school ready relative risk	↔	[b]	↑	↑
Not school ready prevalence	↑	[b]	↑	↑
Low educational achievement 6–11 y relative risk	↑	[b]	↑	↑
Low educational achievement 6–11 y prevalence	↑	[b]	↑	↑
Low educational achievement 12–17 y relative risk	↔	[b]	↔	↑
Low educational achievement 12–17 y prevalence	↑	[b]	↑	↔
Special educational needs relative risk	↑	[b]	↑	↑
Special educational needs prevalence	↑	[b]	↑	↑

↑, increased RR with CI not crossing "1", or increased prevalence compared with term, with CI not overlapping with term; ↓, reduced RR with CI not crossing "1", or decreased prevalence compared with term, with CI not overlapping with term; ↔, difference not statistically significant. ADHD, attention deficit hyperactivity disorder; DD, developmental disorder; SEB, social, emotional, and behavioral disorders.

[a] No data.

[b] Not presented (data available for both 32–33 wk and 34–36 wk groups).

of visual or hearing impairment compared with children born at term was increased in all gestational subgroups, although this only reached statistical significance in the 37 to 38 week gestation group (Supplemental Figs 15–18). There was a small increased risk and prevalence of sleep apnea but its prevalence is low compared with other disorders (Fig 10).

There is an association with reduced gestational age and increased risk and prevalence of all forms of social,

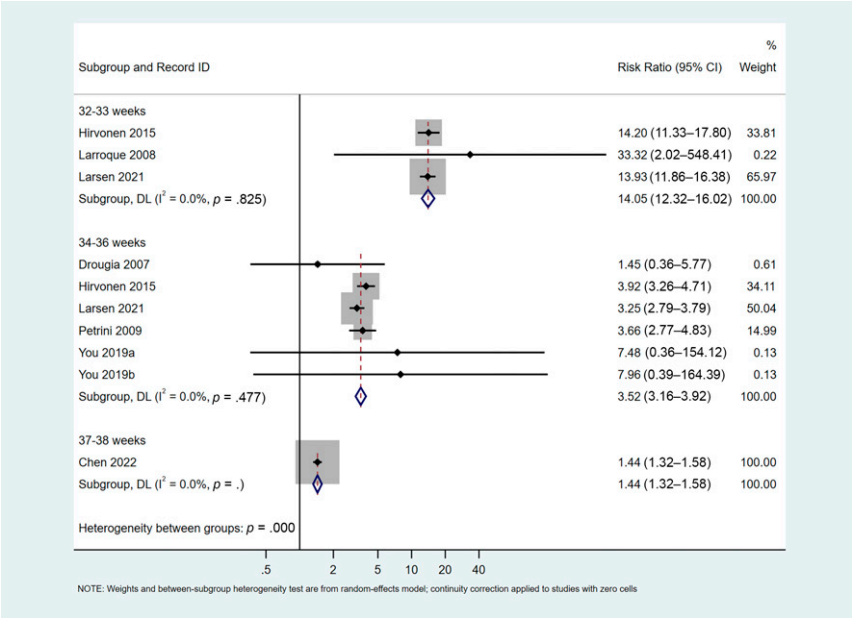

FIGURE 2
Relative risk of cerebral palsy by gestational age.

emotional, and behavioral problems, except externalizing disorders. The most prevalent problem of this type is social problems (eg, showing empathy and playing with other children[28]). There was a small increased risk and prevalence of ASD in the 34 to 36 week group. The only disorder found with neither an increased relative risk nor prevalence among the 32 to 36 week children was externalizing behaviors; this was based on 1 study, as shown in Table 3. There was no increased relative risk of executive function disorders (there is no prevalence estimation since it was reported as a continuous outcome).

Among early term children, prevalence and relative risk of developmental disorder was increased for several disorders: CP, DCD, visual impairment, ADHD, global developmental delay, cognitive impairment, not school ready, low educational achievement, and special education needs (Table 2). There was no data for early term children for: sleep apnea, internalizing behaviors, externalizing behaviors, social problems, motor developmental delay, or cognitive developmental delay.

Sensitivity Analysis

When only the papers with a full term (39–40/41 weeks) comparison group were included, only 1 paper remained in each gestational subgroup for CP and global developmental delay. The overall interpretation was unchanged in all cases (Supplemental Figs 70–73).

Heterogeneity

In general, the heterogeneity statistics (I^2) were 0 (Figs 2–9). Some subgroups had a higher heterogeneity, for example in the educational achievement aged 6 to 11 years meta-analysis (Fig 8). A possible source of heterogeneity was different measurements for developmental disorder; in the CP meta-analysis Larroque 2008, You 2019a, and You 2019b examined participants rather than using linked records, possibly explaining why these studies had a higher prevalence of CP. The different methods used to identify each developmental disorder are shown in Supplemental Table 8. Heterogeneity between subgroups was low.

Publication Bias

The majority of funnel plots (16 of 24) were symmetrical with nonsignificant Egger's tests (14 of 24) (Supplemental Table 9 and Supplemental Figs 48–69 in the supplemental information).

DISCUSSION

Children born between 32 and 38 weeks are at increased risk of screening positive for, or receiving a diagnosis of, a developmental disorder compared with children born at term. In most cases an inverse gradient association with gestational age was demonstrated. The highest increased relative risk compared with children born at term was for children born 32 to 33 weeks for CP, but CP has a low prevalence compared with other developmental disorders.

The association between increased risk and prevalence of global developmental delay or language delay compared with children born at term is evident in all gestational age groups between 32 and 38 weeks. Interpreting

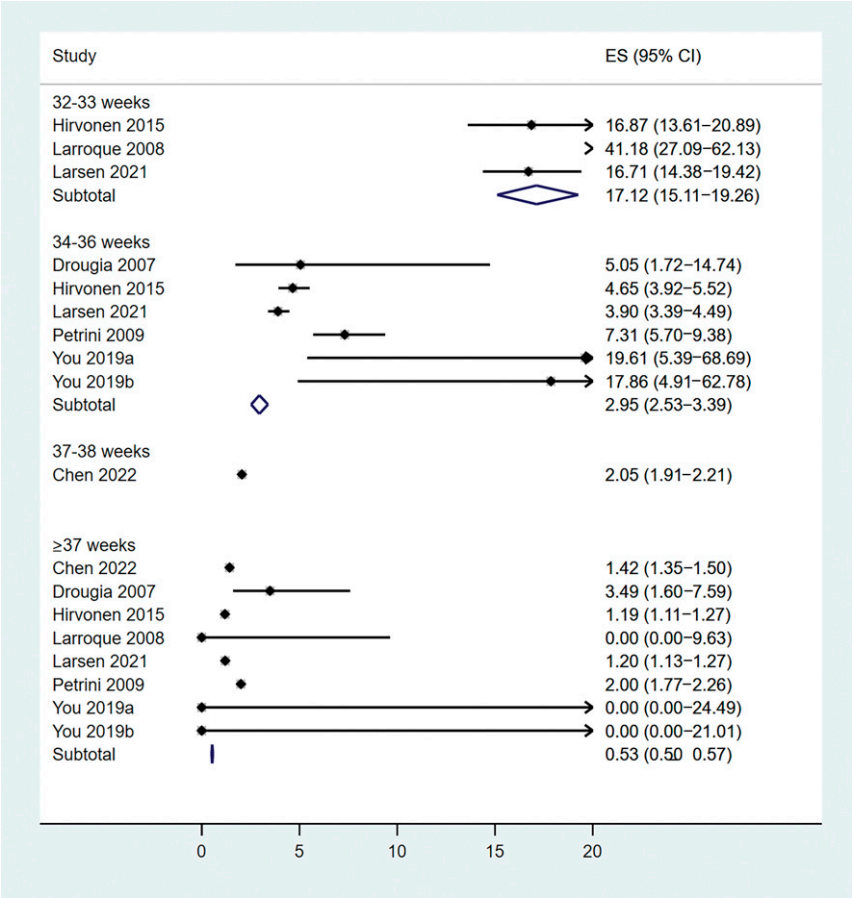

FIGURE 3
Prevalence of cerebral palsy by gestational age.

the cognitive developmental delay meta-analysis is challenging; prevalence was relatively high in the term group, with confidence intervals overlapping the 32 and 36 week group. However, there was an increased relative risk of cognitive developmental delay in the 32 to 36 week group compared with term. It is likely that the picture seen with prevalence is a result of which studies reported different gestational age groups.

In 2 disorders (hearing impairment and ASD), 1 group born 32 to 38 weeks had a lower prevalence of developmental disorder than the term group (Table 2). In both cases this was where the gestational subgroup only included results from 1 study (Table 3). It is likely that this is a peculiarity of the tools used to assess the disorder in that study, since when the relative risks are considered, this effect was not seen.

These findings are largely consistent with previous research that has shown increased risk of developmental disorders among children born moderately preterm, late preterm, and early term.[3,8,10,19] This review demonstrates that difficulties faced by children born 32 to 38 weeks persist through childhood, with evidence of increased risk and prevalence of cognitive impairment and low educational achievement aged 6 to 11 years, in contrast to previous research suggesting developmental delay in preterm infants may be transient.[29,30]

The proportion of children affected by a developmental disorder is generally lower among children born between 32 to 38 weeks compared with extremely preterm children. However, late preterm and early term birth are common; in the United States in 2020, 7.4% of children were born late preterm, whereas only 2.7% were born under 34 weeks.[11] Therefore, small increases in relative risk (compared with full term children) may have a considerable affect, both clinically and economically, at a population level.[30–33]

Developmental disorders affect 35% to 52% of children born extremely or very preterm[31,34] (which is not substantially higher than the prevalence of DCD, social problems, and low educational achievement found in children born 32–38 weeks in this meta-analysis). CP affects 8% to 9% of very preterm children,[29] compared with 1.71% (95% CI: 1.51–1.93) born between 32 and

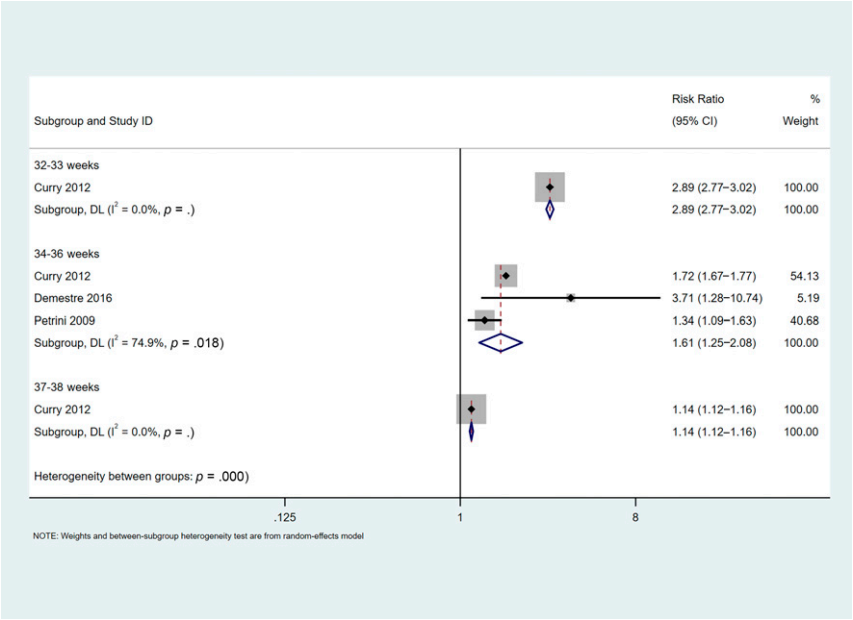

FIGURE 4
Relative risk of global developmental delay by gestational age.

33 weeks in this review. Children born between 32 and 38 weeks may experience a different profile of disorders to extremely preterm children, possibly mediated through different pathways.[13,29,33,35] Birth before full term may be the result of maternal ill health (eg, preeclampsia, gestational diabetes, infection) and a suboptimal intrauterine environment.[33] These antenatal issues may be driving the increased risk and prevalence of developmental disorders, as opposed to the prematurity per se.[7,11,36] Conversely, babies born just a few weeks early have markedly different brain maturation

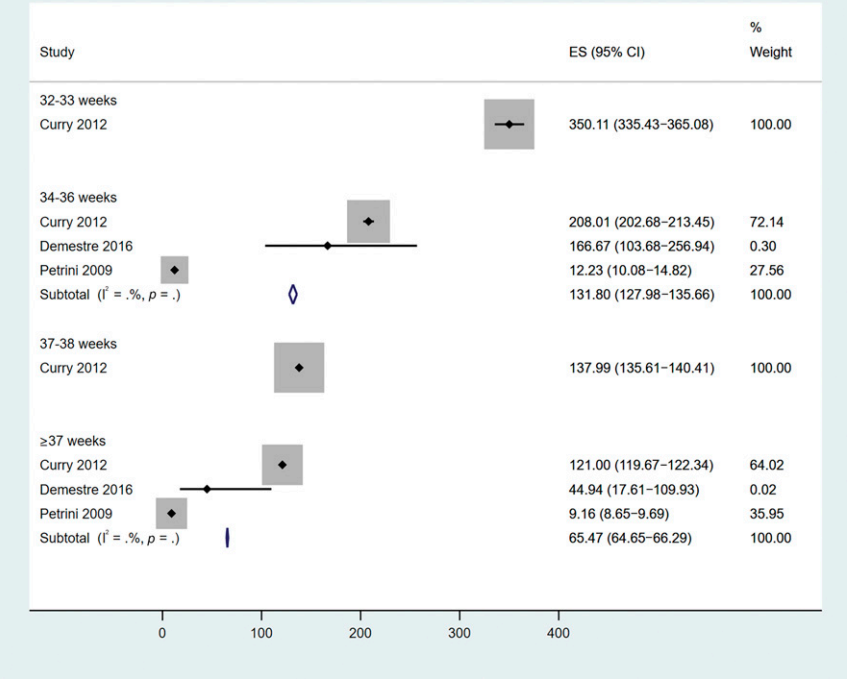

FIGURE 5
Prevalence of global developmental delay by gestational age.

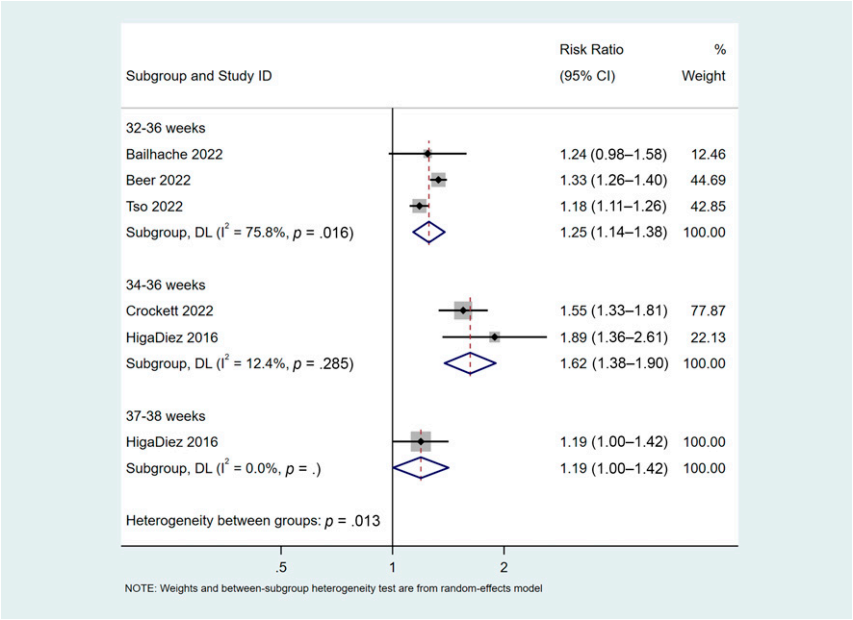

FIGURE 6
Relative risk of ADHD or ADHD symptoms by gestational age.

to full term children.[10,35,37] It is possible that birth between 32 and 38 weeks' gestation may disrupt evolution of neural connections, potentially resulting in developmental disorder.[19,33] Children born before full term are more likely to have medical complications in the immediate neonatal period, in some cases leading directly to a developmental disorder.[19,38] After the neonatal period, children born late preterm are 2 to 3 times more likely to attend the emergency

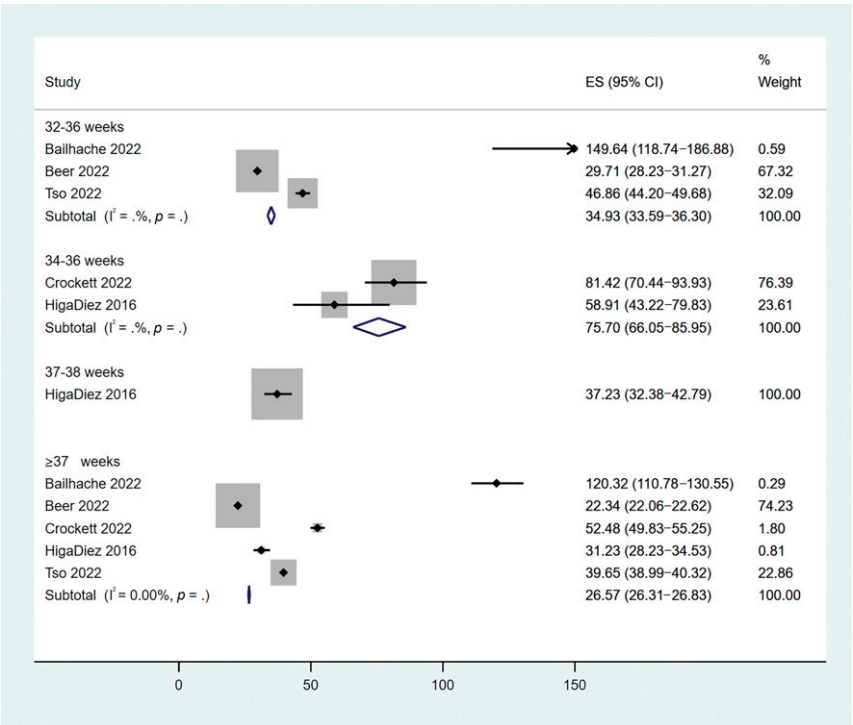

FIGURE 7
Prevalence of ADHD or ADHD symptoms by gestational age.

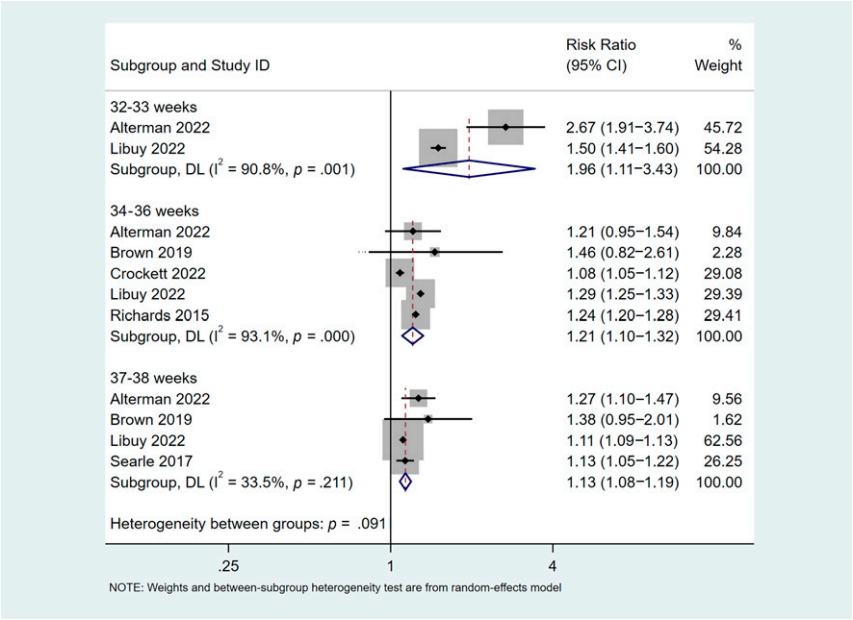

FIGURE 8
Relative risk of low educational achievement aged 6 to 11 years by gestational age.

department or be admitted to hospital.[6,39] The increased medical needs of children born before full term affect both the child and family. Parents of late preterm infants have been shown to have high emotional distress and anxiety levels.[6,40] Furthermore, admission to the neonatal unit is associated with both acute stress and post-traumatic stress disorder among parents.[41] It is plausible that early complications, prolonged admission, or readmission to hospital indirectly affects child development via the negative effect on the whole family.

Strengths and Limitations

This was a broad ranging, comprehensive review. The search strategy identified a large number of studies; there was a total of over 8 million children in the meta-analyses. Including a full range of developmental disorders enabled comparison of prevalence of different developmental disorders across gestational ages. Calculating prevalence meant the increased risk could be contextualized. Although there were a large number of children in total, because each developmental disorder was considered separately according to gestational age subgroups, there were sometimes small numbers in each subgroup (Table 3). There were relatively few studies reporting outcomes for early term children; the subgroup meta-analysis often only contained data from 1 study, although this often represented more children than in the other gestational subgroups combined.

Developmental disorders are, by definition, a heterogeneous group. To determine which conditions to investigate and maximize this review's applicability, we used the NICE guideline, "Developmental follow-up of children and young people born preterm," as a reference.[18] The NICE guideline considers "problems with inattention, impulsivity, or hyperactivity" separately from "executive function problems." However, ADHD is closely associated with impaired executive function, and some have argued that "executive function problems" do not represent a diagnosis as such.[42,43] The NICE guidance also describes increased risk of low educational achievement ("educational attainment" in the UK) among children born preterm. Although there are probably many children who have low educational achievement but do not have a diagnosed developmental disorder, low educational achievement has been demonstrated to be associated with early developmental difficulties.[44] Including educational achievement also gives the opportunity to examine outcomes at a later stage of childhood, demonstrating that the association between birth before full term and developmental disorder can persist into adolescence.

The tools measuring outcomes were numerous and varied, as described in Supplemental Table 8, which likely accounts for some of the different prevalence (eg, DCD Supplemental Fig 13). Furthermore, although some studies used diagnostic codes in medical records to determine their outcome, many studies used questionnaires, tests, and tools (eg, the Ages and Stages Questionnaire) that were not developed to make formal diagnoses, but rather were intended as screening tools for developmental problems.[45] Thus, when considering the results of this review, it is crucial to bear in mind that although some children may screen positive for a potential developmental disorder or be highlighted as a "cause for

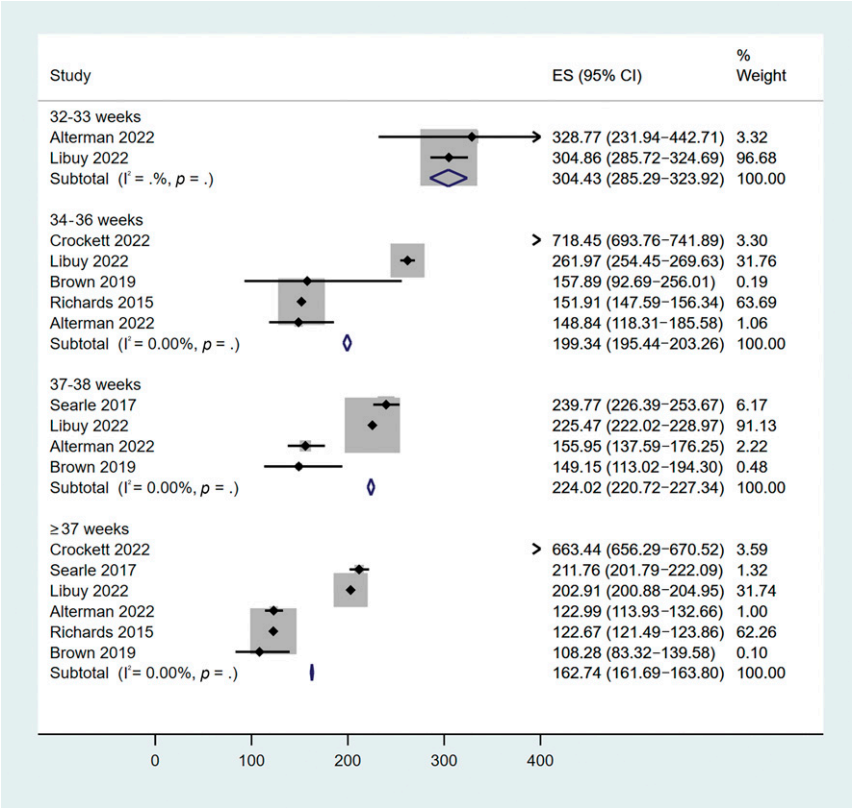

FIGURE 9
Prevalence of low educational achievement aged 6 to 11 years by gestational age.

concern," that does not equate to a formal diagnosis of a specific developmental disorder.

As with other reviews,[10] the children were assessed at different ages and the term comparison groups were variable, for example ≥37 weeks, >37 weeks, ≥39 weeks, 39 to 41 weeks, or 40 weeks. Comparator groups were (where possible) children born at full term (39–40/41 weeks), or if this data were not presented, at term (≥37 weeks). This could account to some extent for why the prevalence of some disorders (eg, not school ready, low educational achievement 6–11 years) is lower in the 37 to 38 week group than in the term group. Although it would have been preferable to have a homogenous term comparator group, only including studies that used a full term (39–40/41 weeks) comparison group would have resulted in a substantial loss of data; of the 76 included studies, only 24 used a full term comparison group. A sensitivity analysis was undertaken for CP, global developmental delay, educational outcomes aged 6 to 11 years, and ADHD, where only the papers with a full term comparison group were included (Supplemental Figs 70–73). In some cases, this resulted in only 1 study in each gestational age subgroup. The overall interpretation was unchanged.

Some studies used atypical cohorts, eg, Drougia 2007, Klassen 2004, and Polic 2017 only included children who admitted to a neonatal unit; in these cases, their term comparator groups would not represent typical term-born children.

The majority of studies were from economically developed countries and all were published in English, possibly limiting generalizability. Outside of the United States, there was limited data on children with non-European heritage; this is important, as race or ethnicity may impact the likelihood of screening positive for, or receiving a diagnosis of, a developmental disorder.[3,18,46]

Implications for Practice

Understanding the long-term implications of birth before full term when balanced against short term risk to the mother and fetus may influence obstetric decision making.[8] It is vital that all healthcare professionals, particularly pediatricians, are well informed of the potential consequences of preterm birth in order that they can give evidence based information to families and so opportunities for early intervention are not missed. Children born at 32 to 38 weeks may benefit from increased monitoring of their development, but most neonatal follow-up programs only apply to children born very preterm, in line with American Academy of Pediatrics guidelines.[6,32,47] However, it is

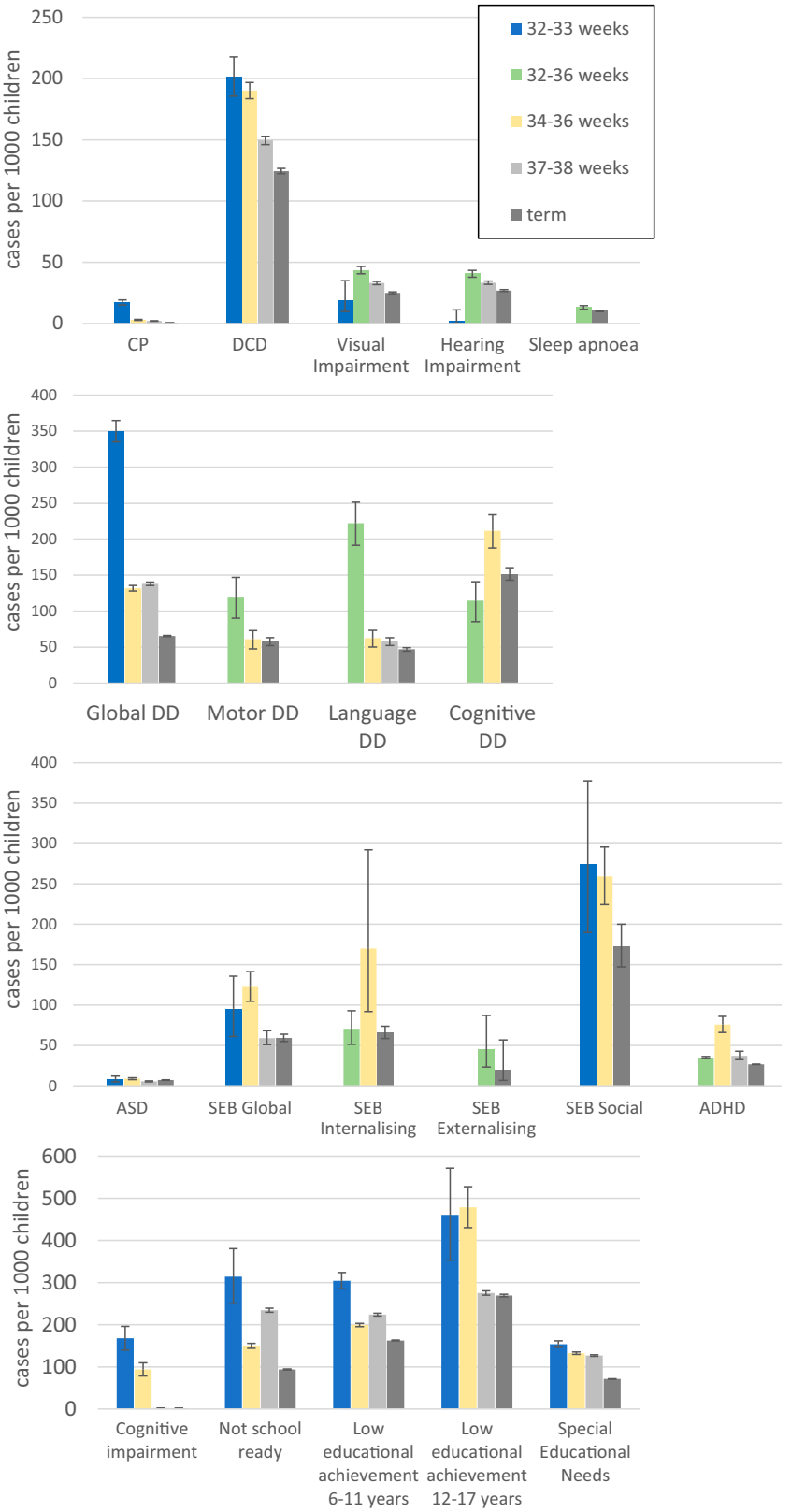

FIGURE 10
Bar chart showing pooled prevalence per 1000 children of developmental disorder by gestational group with 95% confidence intervals.

TABLE 3 Summary Describing the Relative Risk and the Number of Studies and Participants Per Gestational Age Subgroup Per Outcome. Binary Outcomes Unless Specified

Developmental Disorder	32–33 wk	32–36 wk	34–36 wk	37–38 wk	Term	Total
CP						
Relative risk (95% CI)	14.1 (12.3 to 16.0)	NP	3.52 (3.16 to 3.92)	1.44 (1.32 to 1.58)		
Number of children	15 365	NP	87 053	346 859	2 695 512	3 144 789
Number of studies	3	NP	6	1	8	8
DCD						
Relative risk (95% CI)	2.43 (0.82 to 7.25)	ND	1.65 (1.10 to 2.46)	1.15 (1.06 to 1.24)		
Number of children	2445	ND	13 636	42 394	88 244	146 719
Number of studies	2	ND	2	2	2	2
Visual impairment						
Relative risk (95% CI)	7.23 (0.92 to 56.9)	1.42 (0.94 to 2.15)	ND	1.26 (1.20 to 1.32)		
Number of children	484	19 596	ND	70 026	183 047	273 153
Number of studies	1	4	ND	1	5	5
Hearing impairment						
Relative risk (95% CI)	2.32 (0.09 to 56.7)	1.03 (0.35 to 3.04)	ND	1.19 (1.13 to 1.25)		
Number of children	503	19 445	ND	70 053	181 688	271 689
Number of studies	1	2	ND	1	3	3
Sleep apnea						
Relative risk (95% CI)	ND	1.30 (1.15 to 1.46)	ND	ND		
Number of children	ND	22 039	ND	ND	377 952	399 991
Number of studies	ND	1	ND	ND	1	1
SEB global (binary)						
Relative risk (95% CI)	1.12 (0.77 to 1.62)	ND	1.24 (1.04 to 1.48)	1.11 (0.94 to 1.32)		
Number of children	248	ND	1232	2864	10 571	14 915
Number of studies	2	ND	2	1	2	2
SEB global (continuous)						
Standardized mean difference (95% CI)	ND	0.41 (0.23 to 0.59)	0.80 (0.54 to 1.05)	ND		
Number of children	ND	377	126	ND	313	816
Number of studies	ND	1	1	ND	2	2
SEB internalizing						
Relative risk (95% CI)	ND	1.22 (0.89 to 1.69)	0.82 (0.37 to 1.81)	ND		
Number of children	ND	597	53	ND	4368	501
Number of studies	ND	2	1	ND	3	3
SEB externalizing						
Relative risk (95% CI)	ND	2.29 (0.62 to 8.47)	NA	ND		
Number of children	ND	176	NA	ND	151	327
Number of studies	ND	1	NA	ND	1	1
SEB social						
Relative risk (95% CI)	1.51 (1.03 to 2.20)	NP	1.60 (1.04 to 2.46)	ND		
Number of children	84	NP	594	ND	813	1491
Number of studies	1	NP	2	ND	2	2
ADHD (binary)						
Relative risk (95% CI)	ND	1.25 (1.14 to 1.38)	1.62 (1.38 to 1.90)	1.19 (1.00 to 1.42)		
Number of children	ND	7109	2733	5103	1 443 744	1 522 671
Number of studies	ND	3	2	1	5	5
ADHD (continuous)						
Standardized mean difference (95% CI)	ND	0.15 (−0.04 to 0.34)	0.10 (0.06 to 0.15)	0.11 (−0.07 to 0.29)		
Number of children	ND	525	1907	7132	15 494	25 058
Number of studies	ND	3	3	2	7	7
ASD						
Relative risk (95% CI)	1.75 (1.13 to 2.69)	ND	1.42 (1.08 to 1.88)	1.13 (0.98 to 1.29)		
Number of children	2455	ND	25 592	51 307	324 345	403 699
Number of studies	2	ND	3	1	3	3

TABLE 3 Continued

Developmental Disorder	32–33 wk	32–36 wk	34–36 wk	37–38 wk	Term	Total
Global DD						
Relative risk (95% CI)	2.89 (2.77 to 3.02)	NP	1.61 (1.25 to 2.08)	1.14 (1.12 to 1.16)		
Number of children	3973	NP	30 266	79 228	358 670	472 137
Number of studies	1	NP	3	1	3	3
Language DD						
Relative risk (95% CI)	ND	2.15 (0.98 to 4.70)	1.79 (0.95 to 3.36)	1.53 (0.95, 2.47)		
Number of children	ND	745	1673[a]	7109[a]	31 272[a]	40 799[a]
Number of studies	ND	4	2	2	6	6
Motor DD						
Relative risk (95% CI)	ND	1.69 (0.99 to 2.88)	4.26 (0.53 to 34.4)	ND		
Number of children	ND	522	1414	ND	7108	9044
Number of studies	ND	4	3	ND	7	7
Cognitive DD						
Relative risk (95% CI)	ND	2.32 (1.08 to 4.99)	1.29 (1.14 to 1.46)	ND		
Number of children	ND	525	1200	ND	6780	8505
Number of studies	ND	4	1	ND	5	5
Cognitive impairment (binary)						
Relative risk (95% CI)	1.86 (1.39 to 2.48)	ND	1.86 (0.93 to 3.72)	1.16 (1.07 to 1.27)		
Number of children	631	ND	1315	135 185	540 350	677 481
Number of studies	3	ND	4	2	6	6
Cognitive impairment (continuous)						
Standardized mean difference (95% CI)	−0.07 (−0.56 to 0.41)	NP	−0.31 (−0.54 to −0.08)	−0.60 (−1.15 to −0.05)		
Number of children	31	NP	564	469	11 529	12 593
Number of studies	1	NP	4	1	5	5
Executive function (continuous)						
Standardized mean difference (95% CI)	ND	0.33 (−0.08 to 0.74)	−0.06 (−0.49 to 0.37)	ND		
Number of children	ND	45	39	ND	90	174
Number of studies	ND	1	1	ND	2	2
Not school ready relative risk						
Relative risk (95% CI)	1.28 (0.94 to 1.76)	NP	1.31 (1.23 to 1.39)	1.11 (1.08, 1.14)		
Number of children	199	NP	14 485	29 238	239 737	283 659
Number of studies	2	NP	6	4	7	7
Low educational achievement 6–11 yrs						
Relative risk (95% CI)	1.96 (1.11 to 3.43)	NP	1.21 (1.10 to 1.32)	1.13 (1.08, 1.19)		
Number of children	2215	NP	40 586	60 995	472 354	576 150
Number of studies	2	NP	5	4	6	6
Low educational achievement 12–17 yrs						
Relative risk (95% CI)	1.04 (0.82 to 1.33)	NP	1.08 (0.97 to 1.21)	1.03 (1.01 to 1.05)		
Number of children	76	NP	401	28 948	83 073	112 498
Number of studies	1	NP	1	2	2	2
Special educational needs						
Relative risk (95% CI)	1.60 (1.25 to 2.04)	NP	1.36 (1.23 to 1.51)	1.17 (1.09 to 1.26)		
Number of children	8429	NP	53 178	129 778	1 053 459	1 244 844
Number of studies	3	NP	5	3	6	6

ND, data; NP, not presented (data available for both 32–33 wk and 34–36 wk groups).

[a] This does not include Zambrana 2021, as only the results of the regression were presented, therefore the raw numbers could not be extracted.

likely that, especially among the more mature gestations, many children will not have any developmental disorders.[31] Depending on the structure and financing of the healthcare systems, routine appointments for all these children may be impractical and undesirable. A more effective approach would be collaborating with the education sector (which currently bears the majority of the cost associated with prematurity[48]). Teachers should be informed if they have students who are born preterm and early term and receive training on how to support them.[8,49] It is also likely that early childhood risks for poorer outcomes are additive; determining which groups of children born 32 to

38 weeks are most at risk for developmental disorder, selectively following them up, and providing family support would be a pragmatic approach.[6] Empowering parents with information on developmental risks is important, not only for the early recognition of problems, but also to give parents agency.[47] It is currently unclear which children born between 32 and 38 weeks are at the highest risk[32] or to what extent early interventions shown to benefit very preterm children might also benefit children born 32 to 38 weeks.[12,32,48–52]

We have demonstrated that for many gestational subgroups the research into developmental disorders is sparse (Table 3) and gaps in the empirical knowledge persist. In future research, consistent outcome measurements, full term control groups (39–40/41 weeks) and standardized gestational age groups should be used, to allow easier comparison.[8,19,32]

CONCLUSIONS

This review has found evidence of an inverse relationship between birth before full term and the majority of developmental disorders. Low educational achievement, DCD, global developmental delay, and cognitive impairment were the most prevalent disorders among children born 32 to 38 weeks. Some of the increased risks are small but may have significant consequences both clinically and economically at a population level, as birth between 32 and 38 weeks is common. Future research should focus on determining which subgroups of children born 32 to 38 weeks are at particularly high risk and how these children can be supported to reach their potential.

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ABBREVIATIONS

ADHD: attention deficit hyperactivity disorder
ASD: autism spectrum disorder
CI: confidence interval
CP: cerebral palsy
DCD: developmental coordination disorder

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