Cognitive and Educational Outcomes following Preterm Birth or Low Birth Weight: An Umbrella Review and Meta-Analysis

Mingzheng Hu, MMed[1,*], Tiffany Truong, MPhil[1], Sufen Zhu, MPhil[1], Joaquim Vidiella-Martin, PhD[1,2], Samantha Johnson, PhD[3], Maria A. Quigley, MSc[4], Stavros Petrou, PhD[1]

[1] Nuffield Department of Primary Care Health Sciences, University of Oxford, Oxford, United Kingdom

[2] Erasmus School of Economics and Erasmus Centre for Health Economics Rotterdam, Erasmus University Rotterdam, Rotterdam, the Netherlands

[3] School of Healthcare, University of Leicester, Leicester, United Kingdom

[4] National Perinatal Epidemiology Unit, Nuffield Department of Population Health, University of Oxford, Oxford, United Kingdom

Email: mingzheng.hu@phc.ox.ac.uk (Mingzheng Hu); tiffany.truong@seh.ox.ac.uk (Tiffany Truong); sufen.zhu@phc.ox.ac.uk (Sufen Zhu); joaquim.vidiellamartin@phc.ox.ac.uk (Joaquim Vidiella-Martin); sjj19@leicester.ac.uk (Samantha Johnson); maria.quigley@npeu.ox.ac.uk (Maria A. Quigley); stavros.petrou@phc.ox.ac.uk (Stavros Petrou).

[*]**Corresponding Author:**

Mingzheng Hu

Nuffield Department of Primary Care Health Sciences, University of Oxford

Radcliffe Observatory Quarter, Woodstock Road, Oxford OX2 6GG, United Kingdom

Email: mingzheng.hu@phc.ox.ac.uk

Telephone: +4407962630607

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Key Points

Question

Are preterm birth and low birth weight associated with adverse cognitive and educational outcomes?

Findings

In this umbrella review and meta-analysis, preterm birth and low birth weight were associated with lower general cognitive ability and disadvantages across multiple educational domains, and these disadvantages generally increased with earlier gestational age and lower birth weight. Although some associations appeared to attenuate during adolescence, evidence of persistent disadvantages into adulthood was observed for several outcomes.

Meaning

Preterm birth and low birth weight are associated with enduring cognitive and educational disadvantages, highlighting the need for early support and intervention.

Abstract

Importance Advances in perinatal care have improved survival for infants born preterm (<37 weeks' gestation) or with low birth weight (<2500 g), but these individuals remain at increased risk of poorer cognitive and educational outcomes.

Objective To synthesize evidence from systematic reviews on both cognitive and educational outcomes in individuals after preterm birth or with low birth weight using an umbrella review and meta-analysis approach.

DATA SOURCES AND STUDY SELECTION The PubMed, Embase, ERIC, RePEc, EconLit, and Google Scholar databases were searched from inception through April 2025 for systematic reviews examining associations between preterm birth or low birth weight and cognitive or educational outcomes.

Data Extraction and Synthesis Two reviewers independently selected studies, extracted data, and evaluated study quality and risk of bias (following the guidelines from the Joanna Briggs Institute). The effect sizes from the original primary studies included in meta-analyses were reanalyzed and converted to equivalent Hedges g effect sizes. Data were pooled using random-effects models. The subgroup analyses examined associations by gestational age, birth weight, and age. Narrative synthesis supplemented quantitative findings.

Main Outcomes and Measures General cognitive ability (intelligence quotient [IQ]) and 4 domains of educational outcomes (academic attainment, type and length of schooling, need for additional educational support, and educational costs).

Results Forty systematic reviews (22 with meta-analyses and 18 with narrative

syntheses) were included, yielding 788 analyzed effect estimates. Preterm birth or low birth weight was associated with lower IQ (Hedges g, −0.65 [95% CI, −0.69 to −0.61]), poorer attainment in reading (Hedges g, −0.65 [95% CI, −0.87 to −0.43]), lower performance in mathematics (Hedges g, −0.77 [95% CI, −1.03 to −0.50]), lower performance in spelling (Hedges g, −0.56 [95% CI, −0.65 to −0.46]), and greater need for special educational support (Hedges g, 0.58 [95% CI, 0.41 to 0.74]). The associations were stronger at earlier gestational ages and lower birth weights, appeared to attenuate during adolescence, and remained evident into adulthood. Evidence on schooling and educational costs was limited but suggested lower school completion rates and higher educational costs.

Conclusions and Relevance This umbrella review and meta-analysis found that preterm birth and low birth weight were associated with persistent cognitive and educational disadvantages across the life course, underscoring the importance of early identification and long-term monitoring to inform health and education planning.

Cognitive and Educational Outcomes following Preterm Birth or Low Birth Weight: An Umbrella Review and Meta-Analysis

Introduction

Preterm birth (birth at <37 weeks’ gestation) and low birth weight (<2500 g) remain major global public health challenges.[1] Although neonatal survival has improved,[2] individuals born with preterm birth or low birth weight are at increased risk of adverse long-term cognitive and educational outcomes.[3] These disadvantages may persist across the life course and contribute to broader social and economic inequalities,[4] including increased educational support needs and reduced workforce productivity.[5,6]

Despite the growing number of primary studies and systematic reviews on this topic, the evidence base remains fragmented.[7,8] Existing reviews differ in exposure definitions, outcome operationalization, subgroup classification, and analytical approaches,[3,9] leading to heterogeneity in effect estimates and levels of statistical significance across reviews. Moreover, the methodological quality of the systematic reviews varies considerably, and these reviews have not been systematically evaluated within a unified framework for quality assessment and risk of bias evaluation, further limiting the reliability and comparability of existing findings.[10]

To address these gaps, we conducted an umbrella review and meta-analysis to provide a more coherent and reliable synthesis of the evidence on cognitive and educational outcomes after preterm birth or low birth weight. The primary aim was not only to summarize existing systematic reviews, but also to systematically appraise their methodological quality and risk of bias and assess the consistency of evidence across outcomes and life stages. To address heterogeneity arising from inconsistent definitions and analytical approaches, we reanalyzed effect sizes from the original primary studies included in meta-analyses and systematic reviews using a unified analytical framework.

By providing a coherent synthesis of existing evidence, the findings should inform clinical follow-up, educational practice, and policy development in health and education.

Methods

Our review was conducted in accordance with guidelines from the Joanna Briggs Institute (JBI).[11] The protocol was registered in the PROSPERO database (CRD42025618849). The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) reporting guideline was used for this study.

Literature search

We conducted a comprehensive, interdisciplinary literature search across multiple databases. Medical literature was retrieved from PubMed and Embase, educational studies were sourced from ERIC (Education Resources Information Center), and economics-related literature was accessed via RePEc (Research Papers in Economics) and EconLit (Economics Literature). These databases were searched systematically. Google Scholar served as an additional source of evidence. In accordance with the JBI guidelines, the first 10 pages of each Google Scholar search were screened, and potentially relevant results were retained for further evaluation. In addition, we manually screened the reference lists of included articles and conducted targeted gray literature searches on the websites of relevant institutions (the World Health Organization; the United Nations Children's Fund; the United Nations Educational, Scientific and Cultural Organization; the Organisation for Economic Co-operation and Development; and the World Bank). The full search strategies (including all keywords and Boolean operators) appear in eTable 1 through eTable 7 in Supplement 1.

All databases were searched from inception through April 2025. Records were imported into a Covidence library for management and screening. The same 2 reviewers (M.H. and S.Z.) independently conducted the title and abstract screening and full-text review

for all records (were blinded to each other's decisions and selections). At each stage, disagreements regarding study inclusion were resolved through discussion and, if consensus could not be reached, a third reviewer (T.T.) was consulted to make the final decision.

Eligibility criteria were outlined in accordance with the populations, exposures, comparisons, outcomes, and study design reporting structures.[12] Eligible systematic reviews included studies of individuals at any stage (children, adolescents, or adults) of the life course. We considered systematic reviews that examined the association between preterm birth or low birth weight and cognitive or educational outcomes. Based on our pilot search and expert consultation, educational outcomes were categorized into the following 4 domains: (1) academic attainment (eg, standardized test scores in subjects such as mathematics), (2) type and length of schooling (eg, school completion), (3) need for additional educational support (eg, identification of special educational needs), and (4) educational costs (eg, financial expenditures related to schooling). Moreover, cognitive outcomes were measured as general cognitive ability using age-appropriate standardized instruments, including cognitive scales from developmental assessments in infancy and intelligence quotient (IQ) tests in later childhood, adolescence, and adulthood. For consistency, these measures are collectively referred to as IQ throughout the article.

Data extraction, quality assessment, and risk of bias assessment

Data extraction was conducted using the JBI data extraction form for the systematic review and research synthesis analyses.[11] The data items of study authors, year of publication, sources searched, study period, number of included studies, outcomes assessed, and findings were extracted. The methodological quality of the included systematic reviews was assessed using the JBI Critical Appraisal Checklist for Systematic Reviews and Research Syntheses,[11] which contains 11 items covering key aspects such as clarity of the review question, search strategy, and methods for

minimizing bias. Based on the number of criteria met, each review was rated as high, moderate, or low quality. To further assess risk of bias, we applied the Risk of Bias in Systematic Reviews tool,[10] which evaluates key domains, including study eligibility criteria, study identification and selection, data collection and appraisal, and synthesis of findings. Each review was classified as having either a low or high overall risk of bias. To ensure consistency across the review process, the same 2 reviewers (M.H. and S.Z.) were involved in study screening, data extraction, and quality and risk of bias assessment. Disagreements were resolved through discussion, with involvement of a third reviewer (T.T.) when necessary.

Data Synthesis

Within an umbrella review framework, data synthesis was conducted at the primary study level using consistent definitions and analytical procedures, which allowed us to address partial overlap of primary studies across reviews and substantial heterogeneity in exposure definitions, outcome measures, and subgroup classifications, thereby enabling synthesis across reviews. Specifically, data synthesis used both quantitative and narrative approaches. For the quantitative synthesis, we adhered to the meta-umbrella framework proposed by Gosling et al.[13]

The effect estimates were extracted from the originally reported primary studies included in the systematic reviews with meta-analyses selected for this umbrella review. These effect sizes were merged into a single dataset, and duplicate entries referring to the same primary study, outcome, and subgroup were removed prior to analysis. Consequently, each primary study contributed only 1 effect size per outcome per subgroup. When discrepancies or missing information were identified across reviews, the original primary studies were consulted and treated as the authoritative source or, when necessary, clarification was sought by contacting the corresponding authors of the systematic reviews.

Because multiple effect sizes could arise from the same primary study, statistical dependence was addressed using the metaumbrella package in R version 4.4.2 (R Foundation for Statistical Computing), which aggregates effect sizes at the primary study level following established procedures described by Borenstein et al,[14] thereby ensuring that the unit of analysis was the primary study. Random-effects models with restricted maximum likelihood estimation were applied. Between-study heterogeneity was assessed using the I^2 statistic. To enable comparison across outcomes measured using different instruments and effect metrics, all effect estimates were converted into equivalent Hedges g effect sizes,[14] forest plots were generated, and 95% CIs were reported.

Subgroup meta-analyses were conducted according to gestational age, birth weight, and age at assessment. Primary studies were grouped by the maximum gestational age in their samples (<28 weeks, <32 weeks, and <37 weeks), maximum birth weight (<1.0 kg, <1.5 kg, and <2.5 kg), and age range at assessment (infancy, 0–2 years; preschool, 2–4 years; primary school, 4–11 years; secondary school, 11–18 years; and higher education, >18 years). Key characteristics of each primary study, including gestational age range, birth weight range, outcome definitions, and age at assessment, were cross-checked and harmonized using a unified set of criteria prior to conducting the umbrella meta-analyses and the subgroup analyses.

Narrative synthesis summarized narrative findings from systematic reviews with narrative synthesis. The narrative synthesis results are presented in tabular form, and we compiled summary tables describing review characteristics and outcomes.

Results

Included Studies

The results of the literature screening process are illustrated in Figure 1. The literature searches yielded 7562 records, with an additional 2 records identified through citation

tracking, for a total of 7564 records. After removing duplicates and screening titles, abstracts, and the full text, 40 systematic reviews met the inclusion criteria.[3,7–9,15–50] Inter-rater reliability for each stage was excellent (Cohen $\kappa \geq 0.8$).[51] Of these, 22 were systematic reviews with meta-analyses and 18 were systematic reviews with narrative syntheses. The characteristics of the included systematic reviews appear in eTable 8 through eTable 11 in Supplement 1.

Quality and Risk of Bias Assessment

The results of the JBI critical appraisal assessments appear in eTable 12 in Supplement 1. Among the 40 included reviews, 12 were rated as high quality, 24 as moderate quality, and 4 as low quality. The results of the Risk of Bias in Systematic Reviews assessment (showing that 20 reviews were judged to be at low risk of bias, whereas the remaining 20 were classified as high risk) appear in eTables 13 and 14 in Supplement 1. The main sources of lower quality and higher risk of bias included incomplete database search strategies, lack of independent dual screening and data extraction, and limited discussion of heterogeneity and publication bias.

Data Synthesis of Cognitive and Educational Outcomes

The results of the quantitative syntheses appear in Figures 2, 3, 4, and 5 and in the eFigure in Supplement 1. The results of the narrative syntheses appear in eTables 10 and 11 in Supplement 1. More detailed results of the umbrella meta-analyses appear in eTables 15 through 40 in Supplement 1. The dataset used for the umbrella meta-analysis, comprising 788 effect sizes derived from primary studies included in 22 systematic reviews with meta-analyses, appears in eTable 41 in Supplement 1.

General Cognitive Ability

Individuals born preterm or with low birth weight consistently demonstrated significant reductions in general IQ (Hedges g, −0.65 [95% CI, −0.69 to −0.61]; $I^2 = 0.90$), verbal IQ (Hedges g, −0.52 [95% CI, −0.59 to −0.44]; $I^2 = 0.77$), and nonverbal IQ (Hedges g,

−0.63 [95% CI, −0.72 to −0.55]; $I^2 = 0.77$) (Figure 2). The subgroup analyses further demonstrated significant associations across gestational age groups, birth weight, and chronological age groups (Figures 3, 4, and 5 and the eFigure in Supplement 1). The deficit in IQ decreased as gestational age and birth weight increased (Hedges g, −0.94 [95% CI, −1.07 to −0.80] with a gestational age <28 weeks for the outcome of general IQ and −0.57 [95% CI, −0.64 to −0.51] with a gestational age <37 weeks) (Figure 3).

Academic Attainment

The quantitative synthesis demonstrated that individuals born preterm or with low birth weight had poorer academic performance in aggregate measures of reading (Hedges g, −0.65 [95% CI, −0.87 to −0.43]; $I^2 = 0.95$), in reading comprehension (Hedges g, −0.56 [95% CI, −0.71 to −0.41]; $I^2 = 0.82$), in word identification (Hedges g, −0.51 [95% CI, −0.59 to −0.43]; $I^2 = 0.66$), and in pseudoword decoding (Hedges g, −0.81 [95% CI, −1.50 to −0.12]; $I^2 = 0.98$) (Figure 2). Individuals born preterm or with low birth weight had poorer academic performance in aggregate measures of mathematics (Hedges g, −0.77 [95% CI, −1.03 to −0.50]; $I^2 = 0.94$), in mathematical knowledge (Hedges g, −0.66 [95% CI, −0.76 to −0.57]; $I^2 = 0.55$), in calculation (Hedges g, −0.71 [95% CI, −0.92 to −0.51]; $I^2 = 0.82$), in applied math problems (Hedges g, −0.76 [95% CI, −1.03 to −0.49]; $I^2 = 0.88$), and in mathematical fluency (Hedges g, −0.59 [95% CI, −0.79 to −0.40]; $I^2 = 0.46$). For spelling, preterm birth or low birth weight was associated with lower performance (Hedges g, −0.56 [95% CI, −0.65 to −0.46]; $I^2 = 0.65$).

Further subgroup analyses showed that with increasing gestational age or birth weight, the magnitude of associations between preterm birth or low birth weight and reading, mathematics, spelling, and related subdomains gradually decreased (Figures 3 and 4). Associations were statistically significant for all outcomes among individuals born before 28 and 32 gestational weeks but were not significant for pseudoword decoding and mathematical knowledge among those born before 37 gestational weeks. Similarly, the magnitude of the associations weakened progressively with increasing birth weight.

Notably, the estimate for pseudoword decoding in the subgroup with birth weight less than 2.5 kg was based on a single study, limiting the reliability of this finding. In addition, age-stratified analyses indicated that the magnitude of associations attenuated with increasing age. Some subdomains (such as pseudoword decoding and aggregate measures of mathematics) became nonsignificant in older age groups.

In addition to these quantitative results, narrative syntheses revealed disadvantages in academic attainment. Some studies found that teachers rated the academic performance of these individuals lower,[38,46] with reports of lower educational progress rates and poorer school recommendations.[44] Other studies reported that both self-assessments and maternal evaluations of academic performance were also poorer among individuals with preterm birth or low birth weight.[46]

Need for Additional Educational Support

The quantitative synthesis shows that individuals born preterm or with low birth weight were more likely to have special educational needs (Hedges g, 0.58 [95% CI, 0.41 to 0.74]; $I^2 = 0.69$) (Figure 2), corresponding to an odds ratio of 2.85 (95% CI, 2.11 to 3.84). Further subgroup analyses demonstrated significant associations across all preterm subgroups, all low birth weight subgroups, and the 5- to 18-year-old group (Figures 3, 4, and 5 and the eFigure in Supplement 1). The magnitude of the association with special educational needs gradually decreased with increasing gestational age and birth weight.

Type and Length of Schooling

In the quantitative synthesis, only 1 meta-analysis addressed school completion beyond 18 years of age, focusing on the subgroup born with a gestational age from 32 to 37 weeks (Hedges g, −0.07 [95% CI, −0.08 to −0.06]; $I^2 = 0$) (Figure 5), corresponding to an odds ratio of 0.88 (95% CI, 0.87 to 0.90). No meta-analyses were identified for other preterm birth subgroups or for low birth weight regarding school completion. Therefore,

the quantitative results for this outcome in other subgroups do not appear in Figures 2, 3, 4, and 5 and the eFigure in Supplement 1.

However, based on the findings of the narrative syntheses (eTables 10–11 in Supplement 1), children with very low birth weight (<1.5 kg) also had lower high school graduation rates, higher grade retention, and lower participation in postsecondary educational programs. Nearly half of the individuals with very low birth weight pursued vocational education or training rather than higher education, a proportion twice that of comparators. Similar disadvantages were observed earlier in schooling. Individuals born late preterm (34 gestational weeks and 0 days to 36 gestational weeks and 6 days) also had a significantly higher odds of not being ready to start school at 4 years of age and kindergarten retention at 5 years of age.[38]

Educational Costs

Evidence on educational costs was limited. No systematic reviews with meta-analyses were identified, but narrative syntheses indicated that individuals with preterm birth or low birth weight had higher educational costs compared with term birth or normal birth weight. Compared with individuals with a term birth, one study estimated incremental educational costs during the first 18 years after birth at £3978 for children born before 28 gestational weeks, £1463 for children born before 33 gestational weeks, and £494 for children born before 37 gestational weeks (UK pounds are expressed in 2006 prices).[34] A further study found that compared with individuals with a normal birth weight, incremental kindergarten educational costs were $2604 for those with a birth weight less than 1000 g, $1365 for a birth weight of 1000 to 1499 g, and $495 for a birth weight of 1500 to 2499 g (US dollars are expressed in 1988 prices).[45]

Discussion

Using an umbrella review approach, this study synthesized evidence from 40 systematic reviews to assess the associations between preterm birth or low birth weight and

cognitive and educational outcomes. The results indicate robust and persistent associations between preterm birth or low birth weight and disadvantages in both general cognitive ability and multiple educational domains. The magnitude of these associations varied across subgroups defined by gestational age, birth weight, and age.

Individuals born preterm or with low birth weight had lower scores for general IQ, verbal IQ, and nonverbal IQ compared with comparators, suggesting that preterm birth and low birth weight are strongly associated with long-term developmental disadvantages.[53] Overall, preterm birth or low birth weight was associated with a standardized mean difference of −0.65, corresponding to approximately a 10-point difference in IQ scores. Beyond general cognitive ability, these deficits extended to multiple academic domains and a higher prevalence of special educational needs, highlighting that preterm birth and low birth weight are associated with poorer cognitive functioning and educational outcomes.[54]

Evidence regarding school completion and educational costs was more limited. However, available studies suggested lower university graduation rates, higher rates of grade retention, reduced participation in higher education, and greater educational expenditures for individuals born preterm or with low birth weight. These findings suggest that, on average, preterm birth and low birth weight are associated with developmental disadvantages that are reflected in educational outcomes and greater demands on educational and public finance systems.[55]

Subgroup analyses revealed an inverse relationship between the degree of preterm birth or low birth weight and adverse outcomes. However, even those in the moderate categories (preterm birth <37 gestational weeks or birth weight <2.5 kg) exhibited significant difficulties in cognitive and academic domains, indicating that these groups should not be overlooked.[56] Age-based analyses further suggested that certain deficits may diminish in older age groups.[57] [58] Nonetheless, deficits in IQ, core reading skills,

and spelling, as well as special educational needs, were observed throughout the school years and into early adulthood.[59]

Our findings highlight the need to recognize children with preterm birth or low birth weight as an at-risk group and to address their needs through early identification,[60] targeted resources, evidence-based interventions, and coordinated health and education policies.[61] Future research should adopt standardized definitions of preterm birth and low birth weight, broaden outcomes to include educational costs and schooling trajectories, expand evidence from low- and middle-income countries, include more recent primary research in future reviews, and apply rigorous longitudinal designs to strengthen causal inference across the life course.

To our knowledge, this is the first umbrella review to systematically evaluate both the cognitive and educational outcomes in individuals with preterm birth or low birth weight. By synthesizing all available systematic reviews using a highest-level umbrella review framework, we provide comprehensive and directly comparable evidence across multiple outcomes, with improved precision of association estimates. In addition, by harmonizing gestational age and birth weight ranges and ages at assessment across primary studies, we address inconsistencies in subgroup definitions used in prior reviews,[3 7 9] and offer more robust evidence on subgroup-specific associations.

Limitations

Several limitations should be noted. First, because individual-level data were not available, subgroup analyses were based on the maximum gestational age within each primary study sample (<28, <32, and <37 weeks). The gestational age groups of less than 32 weeks and less than 37 weeks differ from the World Health Organization definitions of very preterm (28 gestational weeks and 0 days to 31 gestational weeks and 6 days) and moderate to late preterm (32 gestational weeks and 0 days to 36 gestational weeks and 6 days). These 2 subgroups may also include infants born before

28 gestational weeks, which could result in larger effect size estimates compared with those derived from strictly defined very preterm and moderate to late preterm subgroups. Second, cognitive outcomes in infancy were based on developmental assessments rather than formal IQ tests and are not directly comparable with later IQ measures.

Conclusion

This umbrella review and meta-analysis found that preterm birth and low birth weight were associated with persistent cognitive and educational disadvantages across the life course, underscoring the importance of early identification and long-term monitoring to inform health and education planning.

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Figures

Figure 1. PRISMA flow diagram of the literature search and study selection process

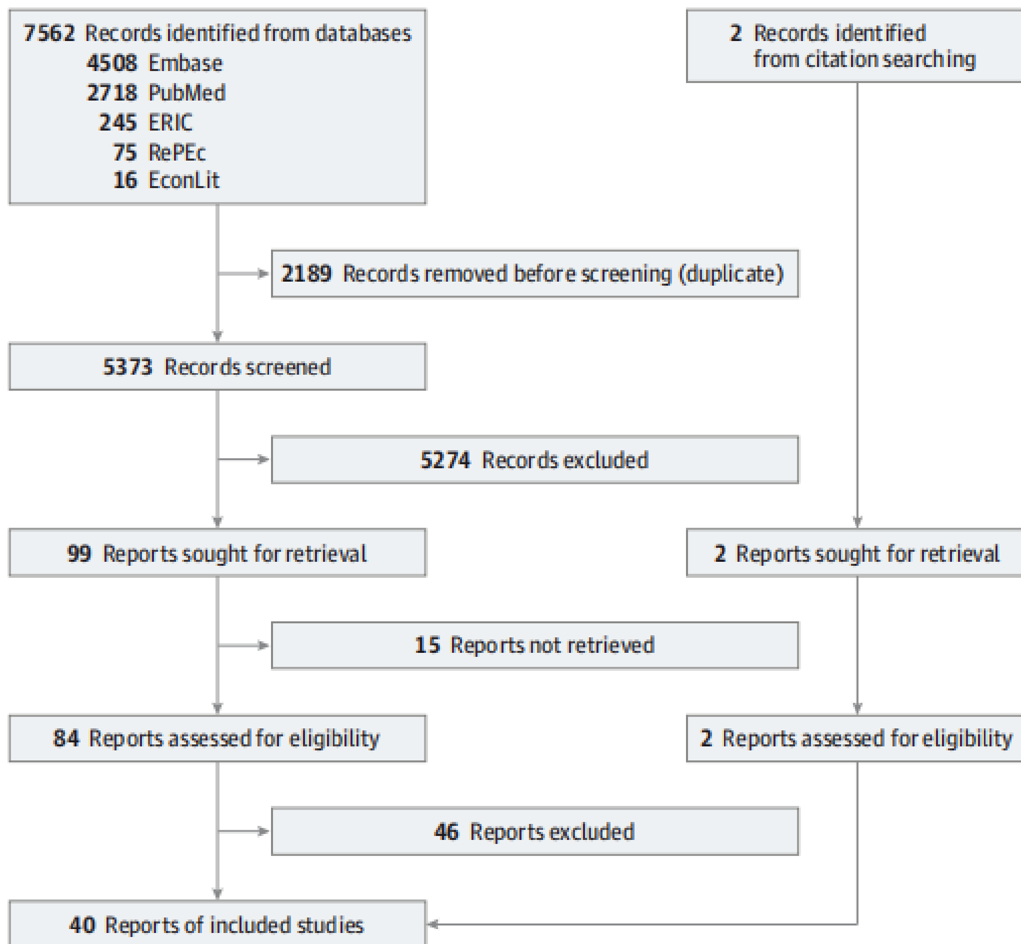
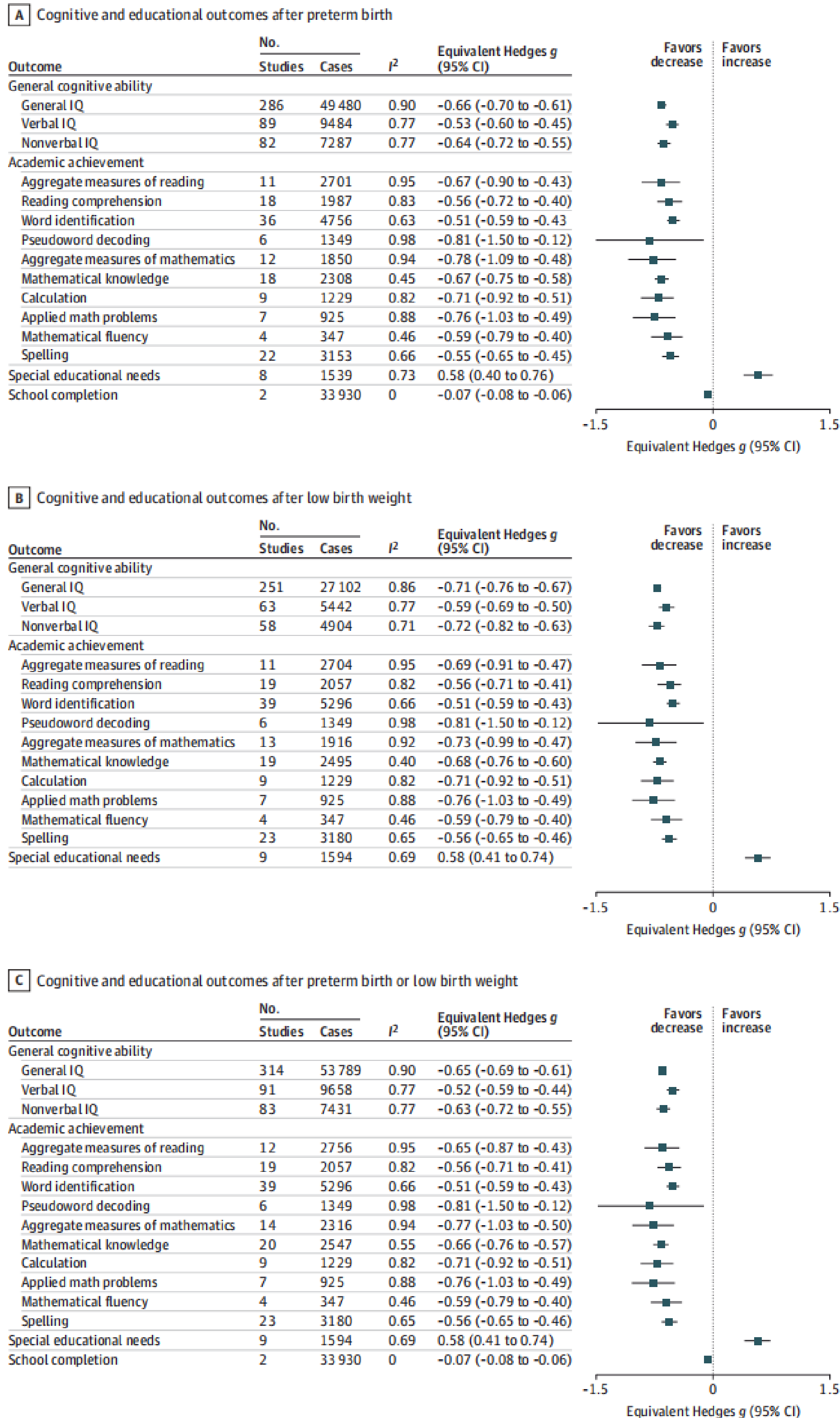


Figure 2. Forest Plots Displaying Umbrella Meta-Synthesis of Cognitive and Educational Outcomes After Preterm Birth or Low Birth Weight



A Cognitive and educational outcomes after preterm birth

Outcome	No. Studies	No. Cases	I^2	Equivalent Hedges g (95% CI)
General cognitive ability				
General IQ	286	49 480	0.90	-0.66 (-0.70 to -0.61)
Verbal IQ	89	9484	0.77	-0.53 (-0.60 to -0.45)
Nonverbal IQ	82	7287	0.77	-0.64 (-0.72 to -0.55)
Academic achievement				
Aggregate measures of reading	11	2701	0.95	-0.67 (-0.90 to -0.43)
Reading comprehension	18	1987	0.83	-0.56 (-0.72 to -0.40)
Word identification	36	4756	0.63	-0.51 (-0.59 to -0.43
Pseudoword decoding	6	1349	0.98	-0.81 (-1.50 to -0.12)
Aggregate measures of mathematics	12	1850	0.94	-0.78 (-1.09 to -0.48)
Mathematical knowledge	18	2308	0.45	-0.67 (-0.75 to -0.58)
Calculation	9	1229	0.82	-0.71 (-0.92 to -0.51)
Applied math problems	7	925	0.88	-0.76 (-1.03 to -0.49)
Mathematical fluency	4	347	0.46	-0.59 (-0.79 to -0.40)
Spelling	22	3153	0.66	-0.55 (-0.65 to -0.45)
Special educational needs	8	1539	0.73	0.58 (0.40 to 0.76)
School completion	2	33 930	0	-0.07 (-0.08 to -0.06)

B Cognitive and educational outcomes after low birth weight

Outcome	No. Studies	No. Cases	I^2	Equivalent Hedges g (95% CI)
General cognitive ability				
General IQ	251	27 102	0.86	-0.71 (-0.76 to -0.67)
Verbal IQ	63	5442	0.77	-0.59 (-0.69 to -0.50)
Nonverbal IQ	58	4904	0.71	-0.72 (-0.82 to -0.63)
Academic achievement				
Aggregate measures of reading	11	2704	0.95	-0.69 (-0.91 to -0.47)
Reading comprehension	19	2057	0.82	-0.56 (-0.71 to -0.41)
Word identification	39	5296	0.66	-0.51 (-0.59 to -0.43)
Pseudoword decoding	6	1349	0.98	-0.81 (-1.50 to -0.12)
Aggregate measures of mathematics	13	1916	0.92	-0.73 (-0.99 to -0.47)
Mathematical knowledge	19	2495	0.40	-0.68 (-0.76 to -0.60)
Calculation	9	1229	0.82	-0.71 (-0.92 to -0.51)
Applied math problems	7	925	0.88	-0.76 (-1.03 to -0.49)
Mathematical fluency	4	347	0.46	-0.59 (-0.79 to -0.40)
Spelling	23	3180	0.65	-0.56 (-0.65 to -0.46)
Special educational needs	9	1594	0.69	0.58 (0.41 to 0.74)

C Cognitive and educational outcomes after preterm birth or low birth weight

Outcome	No. Studies	No. Cases	I^2	Equivalent Hedges g (95% CI)
General cognitive ability				
General IQ	314	53 789	0.90	-0.65 (-0.69 to -0.61)
Verbal IQ	91	9658	0.77	-0.52 (-0.59 to -0.44)
Nonverbal IQ	83	7431	0.77	-0.63 (-0.72 to -0.55)
Academic achievement				
Aggregate measures of reading	12	2756	0.95	-0.65 (-0.87 to -0.43)
Reading comprehension	19	2057	0.82	-0.56 (-0.71 to -0.41)
Word identification	39	5296	0.66	-0.51 (-0.59 to -0.43)
Pseudoword decoding	6	1349	0.98	-0.81 (-1.50 to -0.12)
Aggregate measures of mathematics	14	2316	0.94	-0.77 (-1.03 to -0.50)
Mathematical knowledge	20	2547	0.55	-0.66 (-0.76 to -0.57)
Calculation	9	1229	0.82	-0.71 (-0.92 to -0.51)
Applied math problems	7	925	0.88	-0.76 (-1.03 to -0.49)
Mathematical fluency	4	347	0.46	-0.59 (-0.79 to -0.40)
Spelling	23	3180	0.65	-0.56 (-0.65 to -0.46)
Special educational needs	9	1594	0.69	0.58 (0.41 to 0.74)
School completion	2	33 930	0	-0.07 (-0.08 to -0.06)

Figure 3. Forest Plots Displaying Umbrella Meta-Synthesis of Cognitive and Educational Outcomes by Gestational Age

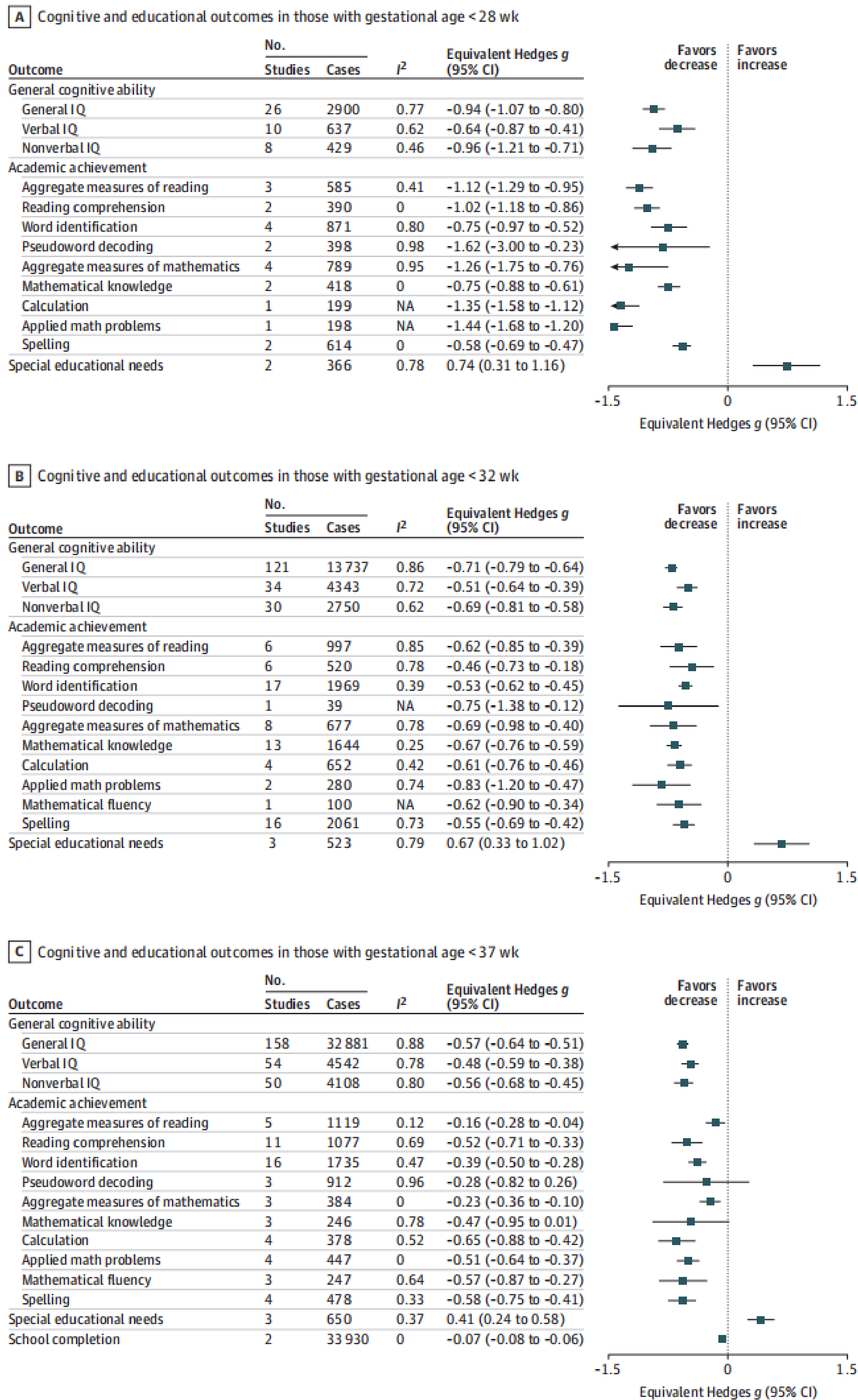
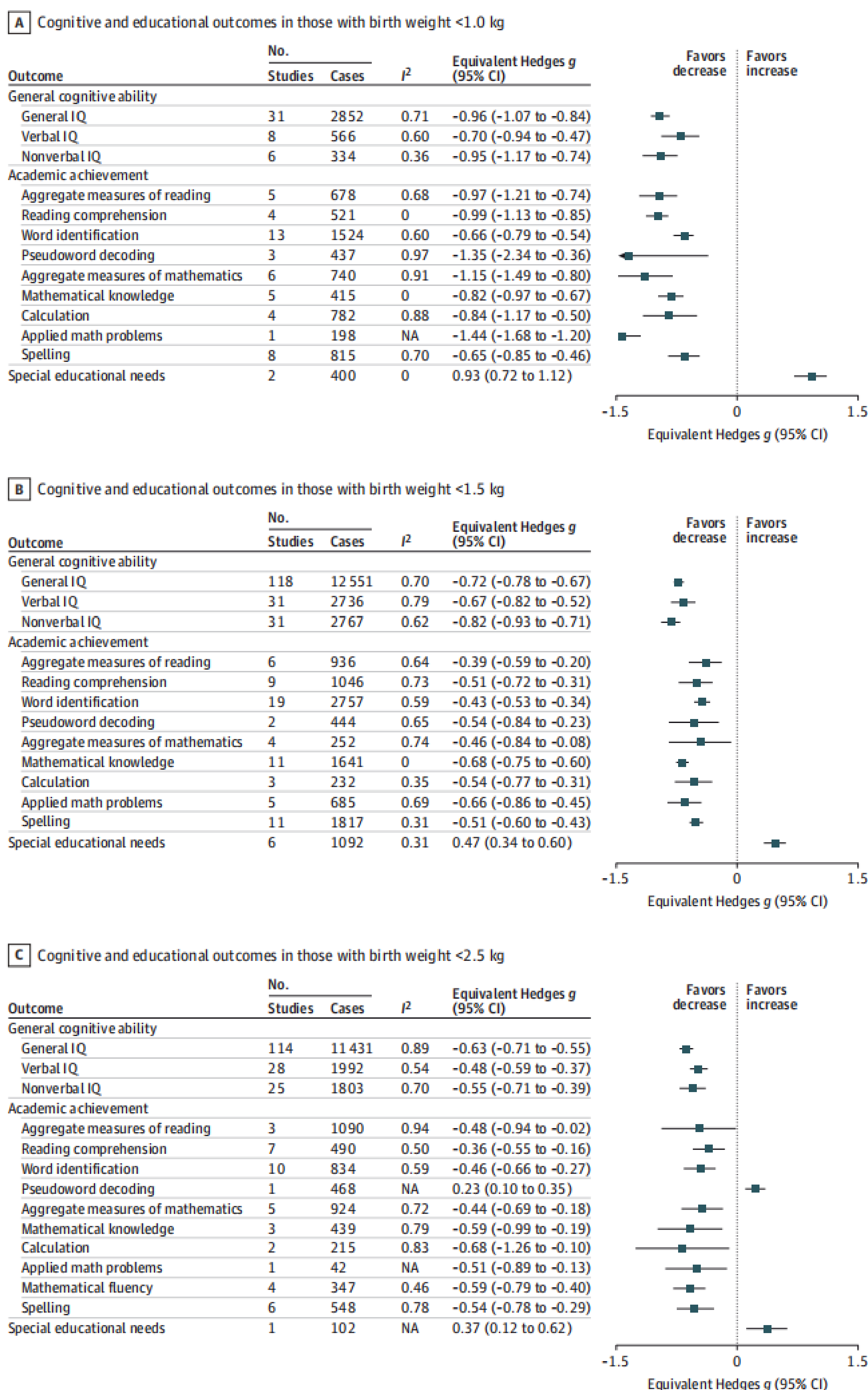


Figure 4. Forest Plots Displaying Umbrella Meta-Synthesis of Cognitive and Educational Outcomes by Birth Weight



A Cognitive and educational outcomes in those with birth weight <1.0 kg

Outcome	No. Studies	No. Cases	I^2	Equivalent Hedges g (95% CI)
General cognitive ability				
General IQ	31	2852	0.71	-0.96 (-1.07 to -0.84)
Verbal IQ	8	566	0.60	-0.70 (-0.94 to -0.47)
Nonverbal IQ	6	334	0.36	-0.95 (-1.17 to -0.74)
Academic achievement				
Aggregate measures of reading	5	678	0.68	-0.97 (-1.21 to -0.74)
Reading comprehension	4	521	0	-0.99 (-1.13 to -0.85)
Word identification	13	1524	0.60	-0.66 (-0.79 to -0.54)
Pseudoword decoding	3	437	0.97	-1.35 (-2.34 to -0.36)
Aggregate measures of mathematics	6	740	0.91	-1.15 (-1.49 to -0.80)
Mathematical knowledge	5	415	0	-0.82 (-0.97 to -0.67)
Calculation	4	782	0.88	-0.84 (-1.17 to -0.50)
Applied math problems	1	198	NA	-1.44 (-1.68 to -1.20)
Spelling	8	815	0.70	-0.65 (-0.85 to -0.46)
Special educational needs	2	400	0	0.93 (0.72 to 1.12)

B Cognitive and educational outcomes in those with birth weight <1.5 kg

Outcome	No. Studies	No. Cases	I^2	Equivalent Hedges g (95% CI)
General cognitive ability				
General IQ	118	12 551	0.70	-0.72 (-0.78 to -0.67)
Verbal IQ	31	2736	0.79	-0.67 (-0.82 to -0.52)
Nonverbal IQ	31	2767	0.62	-0.82 (-0.93 to -0.71)
Academic achievement				
Aggregate measures of reading	6	936	0.64	-0.39 (-0.59 to -0.20)
Reading comprehension	9	1046	0.73	-0.51 (-0.72 to -0.31)
Word identification	19	2757	0.59	-0.43 (-0.53 to -0.34)
Pseudoword decoding	2	444	0.65	-0.54 (-0.84 to -0.23)
Aggregate measures of mathematics	4	252	0.74	-0.46 (-0.84 to -0.08)
Mathematical knowledge	11	1641	0	-0.68 (-0.75 to -0.60)
Calculation	3	232	0.35	-0.54 (-0.77 to -0.31)
Applied math problems	5	685	0.69	-0.66 (-0.86 to -0.45)
Spelling	11	1817	0.31	-0.51 (-0.60 to -0.43)
Special educational needs	6	1092	0.31	0.47 (0.34 to 0.60)

C Cognitive and educational outcomes in those with birth weight <2.5 kg

Outcome	No. Studies	No. Cases	I^2	Equivalent Hedges g (95% CI)
General cognitive ability				
General IQ	114	11 431	0.89	-0.63 (-0.71 to -0.55)
Verbal IQ	28	1992	0.54	-0.48 (-0.59 to -0.37)
Nonverbal IQ	25	1803	0.70	-0.55 (-0.71 to -0.39)
Academic achievement				
Aggregate measures of reading	3	1090	0.94	-0.48 (-0.94 to -0.02)
Reading comprehension	7	490	0.50	-0.36 (-0.55 to -0.16)
Word identification	10	834	0.59	-0.46 (-0.66 to -0.27)
Pseudoword decoding	1	468	NA	0.23 (0.10 to 0.35)
Aggregate measures of mathematics	5	924	0.72	-0.44 (-0.69 to -0.18)
Mathematical knowledge	3	439	0.79	-0.59 (-0.99 to -0.19)
Calculation	2	215	0.83	-0.68 (-1.26 to -0.10)
Applied math problems	1	42	NA	-0.51 (-0.89 to -0.13)
Mathematical fluency	4	347	0.46	-0.59 (-0.79 to -0.40)
Spelling	6	548	0.78	-0.54 (-0.78 to -0.29)
Special educational needs	1	102	NA	0.37 (0.12 to 0.62)

Figure 5. Forest Plots Displaying Umbrella Meta-Synthesis of Cognitive and Educational Outcomes After Preterm Birth and Low Birth Weight by Age Group