


BMJ Open Association between birth weight and neurodevelopment at age 1–6 months: results from the Wuhan Healthy Baby Cohort

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ABSTRACT

Objective The association between birth weight and infants' neurodevelopment is not well understood. We aimed to examine the impact of birth weight on neurodevelopment of infants at age 1–6 months using data from the Wuhan Healthy Baby Cohort (WHBC) study. **Setting and participants** This is a prospective cohort study of 4026 infants from the WHBC study who were born at the Women and Children's Hospital of Wuhan, China between October 2012 and September 2013 and who had complete healthcare records within 6 months after birth. Participants were categorised into three groups according to their birth weight: low birth weight (LBW; birth weight <2500 g), normal birth weight (2500 g ≤ birth weight <4000 g) and macrosomia (birth weight ≥4000 g). **Main outcome measures** The main outcomes were development quotient (DQ) and clinical diagnosis of neurodevelopmental delay. Both adjusted regression coefficients and ORs were estimated for LBW and macrosomia.

Results Of the 4026 infants, 166 (4.12%) were of LBW and 237 (5.89%) were with macrosomia. Adjusted regression coefficients of LBW and macrosomia for gross motor DQ were –11.18 (95% CI –11.36 to 10.99) and 0.49 (95% CI 0.36 to 0.63), fine motor DQ –6.57 (95% CI –6.76 to –6.39) and –2.73 (95% CI –2.87 to –2.59), adaptability DQ –4.87 (95% CI –5.05 to –4.68) and –1.19 (95% CI –1.33 to –1.05), language DQ –6.23 (95% CI –6.42 to –6.05) and 0.43 (95% CI 0.29 to 0.57), and social behaviour DQ –6.82 (95% CI –7.01 to –6.64) and 1.10 (95% CI 0.96 to 1.24). Adjusted OR of LBW for clinical diagnosis of 'neurodevelopmental delay' in gross motor was 2.43 (95% CI 1.65 to 3.60), fine motor 1.49 (95% CI 1.01 to 2.19) and adaptability 1.56 (95% CI 1.06 to 2.31). LBW has no significant effects on 'neurodevelopmental delay' in language and social behaviour, and macrosomia has no significant effects on clinical diagnosis of 'neurodevelopmental delay' in all domains.

Conclusion Both LBW and macrosomia are associated with infants' DQ, and LBW increases the risk of being diagnosed with 'neurodevelopmental delay' in gross motor, fine motor and adaptability among infants aged 1–6 months.

Strengths and limitations of this study

- The study used a prospective cohort design to investigate the association of birth weight with neurodevelopment in infants aged 1–6 months in China.
- Potential confounders including the method of delivery, number of prenatal visits, maternal active or passive smoking, gestational age, gender, birth length, asphyxia neonatorum, and prenatal sociodemographic information were adjusted.
- The study did not have data on infants' neurodevelopment after 6 months of age, which were required to further demonstrate the effects of birth weight on long-term neurodevelopment.
- There are only few neurodevelopmental assessment items for infants aged 1–6 months in the revised Gesell Development Scale (GDS), leading to less sensitive assessment results, and GDS is not commonly used in Western countries, making it difficult to compare the results with studies from Western countries.

INTRODUCTION

Birth weight (BW) is a strong indicator of maternal and newborn health and nutrition. Low birth weight (LBW) increases the risk of death in the early months and years of a child's life, and those who survive tend to have impaired immune function and increased risk of infectious diseases. They are also likely to remain undernourished, with reduced muscle strength, cognitive abilities and IQ throughout their lives.^{1 2} It is estimated that more than 22 million infants are of LBW annually, and majority of them are in low-income and middle-income countries,³ accounting for 60%–80% of all neonatal deaths worldwide.⁴ In China, it is reported that the rate of LBW was significantly reduced from 4.4% in 2006 to 2.4% in 2012.⁵ Despite remarkable achievement made in combating LBW, enormous challenges remain. Evident in national figures are numerous disparities

within the country, with high rates of LBW being reported in undeveloped and remote areas.⁶ With the survival rate of LBW infants greatly improved due to advancements in medical technology and neonatal care, new problems such as growth delay and neurodevelopmental disorders in infants are emerging.⁷

As BW is an important indicator of health status of a fetus, it has profound impact on a child's health and development. It is believed that BW reflects the intrauterine nutritional status of the fetus, which usually affects physical development, including neurodevelopment within 3 years.⁸ The impact of BW can be intensified through acquired environmental factors that facilitate the development of diseases later in life. Recent studies have shown that the association between birth order, which is a proxy for pathogen exposure, and childhood leukaemia may be changed by BW, making children more susceptible to leukaemia.⁹ Additionally, BW has been reported to have an association with increased risk of chronic disease development, such as type 2 diabetes, abdominal obesity and hypertension.¹⁰ Studies have also shown that LBW infants' physical and neurobehavioural development lags behind infants with normal birth weight (NBW) within 12 months,^{11 12} and LBW infants have increased risk of attention deficit hyperactivity disorder, cerebral palsy, visual impairment and deafness.^{13 14}

Although there is evidence that LBW is a risk factor for neurodevelopmental delay, few studies have been conducted to confirm this association in developing and undeveloped countries such as in China,⁷ where majority of newborns of LBW are born. The available evidence from high-income countries cannot be generalised across the world because neurodevelopment can be influenced by many factors such as socioeconomic and culture factors, which greatly vary between developing and developed countries.¹⁵ China is the largest developing country in the world and is the first country to implement one-child policy nearly 40 years ago.¹⁶ Fewer studies have investigated the impact of BW on neurodevelopment and at the early stage of infancy, which is the best time to identify at-risk babies and to intervene, although the policies and interventions have been progressive in achieving positive maternal and child healthcare outcomes.¹⁷ In this study, we used a prospective cohort design to assess the impact of BW on neurodevelopment in infants at age 1–6 months.

MATERIALS AND METHODS

Data sources

Data for this study were extracted from the Wuhan Healthy Baby Cohort (WHBC), specifically designed to investigate factors associated with child growth and development. The detailed proposal of this cohort has been described previously.¹⁸ In the present study, we included a subgroup of infants who were born at the Women and Children's Hospital of Wuhan, China between October 2012 and September 2013 and who have complete healthcare

records within 6 months after birth. Data on antenatal, labour and postnatal care were extracted from their mothers' healthcare records. The unambiguous linkage of healthcare records of infants and their mothers was feasible due to the unique identifier assigned at birth and which is used in the medical information system of the hospitals. Participants were excluded if over 15% of information on their records was missing. Participants who had birth defects, who had been admitted to neonatal intensive care unit and who had neonatal sepsis were also excluded. We finally incorporated 4026 infants after excluding 24 infants with birth defects and 116 participants with incomplete medical records.

BW measurement and classification

BW is defined as the first weight taken within 1 hour of birth, measured by obstetricians or midwives using a baby scale (accuracy 10 g) while the baby's body remained dry and unwrapped. In this study, BW was categorised into LBW (BW <2500 g), NBW (2500 g ≤ BW <4000 g) and macrosomia (BW ≥4000 g) according to the diagnostic criteria of the American College of Obstetricians and Gynecologists.¹⁹ BW categories in the medical information system of Women and Children's Medical and Healthcare Center of Wuhan were coded using the International Classification of Diseases, Tenth Revision. We ascertained the following diagnosis: LBW (code P07.151) and macrosomia (code O33.501).

Neurodevelopmental assessment

The Gesell Development Scale (GDS), developed by Gesell and Amatruda,²⁰ is a useful tool to determine the integrity and maturity of the nervous system in children. The Chinese version of GDS was revised by the Chinese Pediatric Association in 1986 and has been shown to have strong internal reliability and validity.²¹ It has been widely used to evaluate the function of the nervous system²² and to identify whether the nerve muscle or sensory system is defective.²³ It is also used to clinically diagnose developmental delay in infants and children.²⁴ The items of the Chinese version of GDS are grouped into five neurodevelopmental domains: gross motor, fine motor, adaptability, language and social behaviour. Specifically, gross motor includes raising the head, standing and working; fine motor includes hand control and balance; adaptability includes imitation, discriminative performance and perception; language was assessed by means of vocabulary, word comprehension and conversation; and social behaviour includes reactions to persons, personal habits and acquired information.

All of the neurodevelopmental tests were assessed at the Developmental Neuropsychology Laboratory and at age 1–6 months by four trained paediatricians, who were 'blind' to the prenatal and perinatal background of the infants. Maturity age can be used to calculate a development quotient (DQ), which is the maturity age divided by the chronological age, multiplied by 100.²⁵ DQ is corrected if the infant is preterm. Higher DQ is always associated

with better neurodevelopment. According to the Chinese norm, the DQ scores for the total and the five clinical domains were classified into 'low ($DQ < 70$)', 'middle and lower ($70 \leq DQ \leq 84$)', 'medium ($85 \leq DQ \leq 114$)', 'middle and upper ($115 \leq DQ \leq 129$)' or 'high ($DQ \geq 130$)' level. Neurodevelopmental delay can be diagnosed when the infant's neurodevelopmental status was rated as 'middle and lower' and 'low'; relevant clinical intervention should also be performed.²⁶

Covariables

Covariables included the method of delivery (natural or caesarean delivery), number of prenatal visits, maternal active or passive smoking (yes or no), gestational age (continuous data), gender (boy or girl), birth length (continuous data), asphyxia neonatorum (yes or no), and prenatal sociodemographic information such as maternal and paternal education.

Statistical analysis

Mean and SD or frequencies and percentages were used to describe the characteristics of the study participants. We calculated DQ and made a neurodevelopmental diagnosis of the five domains for each infant, both of which were examined as the outcomes. Two methods were used to examine the association between DQ and infants' BW: first, we used one-way analysis of variance (ANOVA) to compare the mean of DQ among different BW categories, and then the prediction of BW was examined with adjustment for other covariables in generalised linear model (GLM) with DQ as the outcome.

Also, the association between BW and the diagnosis of neurodevelopmental domains was examined in two ways. First, χ^2 test was used to analyse the incidence of neurodevelopmental delay among different categories of BW. Second, we used BW as the independent variable and neurodevelopmental diagnosis as the dependent variable, and entered the control variables into the binary logistic regression models, and estimated the OR to predict the neurodevelopmental diagnosis.

In both GLM and logistic regression analyses, we adjusted for prenatal factors (maternal active and passive smoking, and number of pregnancy tests), perinatal factors (gender of infants, delivery mode, asphyxia neonatorum and birth length) and maternal demographic factors (gestational weeks and education level of parents) that may be potential confounders of the association of BW with neurodevelopment. All statistical analyses were conducted using SPSS V.15.0. Statistical significance was defined as a *p* value less than 0.05, and all tests were two-sided.

Patient and public involvement

This study was done without patient involvement. Patients were not invited to comment on the study proposal and were not consulted to develop patient relevant outcomes or to interpret the results. Patients were not invited to

contribute to the writing and editing of this document for readability or accuracy.

RESULTS

Overview

The sociodemographic and clinical characteristics of the participants are shown in [table 1](#). Of the 4026 infants, 55.8% were boys. The mean gestational age was 38.8 ± 1.3 weeks, with a mean BW of 3300.7 ± 4.6 g and a mean birth length of 50.1 ± 1.8 cm. Of the infants, 0.2% (7 of 4026) had neonatal asphyxia, 5.9% (237 of 4026) had macrosomia and 4.1% (166 of 4026) had LBW. Significant associations between BW and gender, birth length, gestational age, mode of delivery and number of prenatal tests were found. The median time of neurodevelopment assessment was 3.7 (IQR: 2.5–4.1) months.

Association of BW with DQ

[Table 2](#) shows the associations between BW and DQ in different domains of neurodevelopment. One-way ANOVA found BW was significantly associated with DQ in gross motor ($F=62.082$, $p < 0.001$), fine motor ($F=41.797$, $p < 0.001$), adaptability ($F=13.839$, $p < 0.001$), language ($F=14.206$, $p < 0.001$) and social behaviour ($F=19.279$, $p < 0.001$). The DQ between the different BW groups in different neurological domains was further compared, and the results are shown in online supplementary appendix 1. DQ in all neurological domains of LBW infants is significantly lower than NBW and macrosomia infants, while there was no significance between NBW and macrosomia infants in all neurological domains. GLM analysis (see online supplementary appendix 2) demonstrated a negative linear relationship between LBW and DQ in gross motor ($B=-11.18$, 95% CI -11.36 to -10.99), fine motor ($B=-6.57$, 95% CI -6.76 to -6.39), adaptability ($B=-4.87$, 95% CI -5.05 to -4.68), language ($B=-6.23$, 95% CI -6.42 to -6.05) and social behaviour ($B=-6.82$, 95% CI -7.01 to -6.64). There was negative linear relationship between macrosomia and DQ in fine motor ($B=-2.73$, 95% CI -2.87 to -2.59) and adaptability ($B=-1.19$, 95% CI -1.13 to -1.05), and positive linear relationship between macrosomia and DQ in gross motor ($B=0.49$, 95% CI 0.36 to 0.63), language ($B=0.43$, 95% CI 0.29 to 0.57) and social behaviour ($B=1.10$, 95% CI 0.96 to 1.24).

Association of BW with neurodevelopmental diagnosis

[Table 3](#) shows the neurodevelopmental delay in five domains and its association with BW. Significantly, χ^2 tests found BW was associated with neurodevelopmental delay in gross motor ($\chi^2=107.255$, $p < 0.001$), fine motor ($\chi^2=70.295$, $p < 0.001$) and adaptability ($\chi^2=9.073$, $p=0.011$). Binary logistic regression model (see online supplementary appendix 3) indicated LBW was a risk factor of infants' neurodevelopmental delay in gross motor (adjusted OR (aOR)=2.43, 95% CI 1.65 to 3.60), fine motor (aOR 1.49, 95% CI 1.01 to 2.19) and

Table 1 Demographic characteristics of participants

	Birth weight			Total (N=4026)
	LBW	NBW	Macrosomia	
	(n=166)	(n=3623)	(n=237)	
Parental demographic factors				
Gestational age* (weeks), mean±SD	36.1±2.2	38.9±1.2	39.4±0.9	38.8±1.3
Mothers' education, n (%)				
Bachelor or above	51 (30.7)	1333 (36.8)	84 (35.4)	1468 (36.5)
Below bachelor	115 (69.3)	2290 (63.2)	153 (64.6)	2558 (63.5)
Fathers' education, n (%)				
Bachelor or above	53 (31.9)	1428 (39.4)	88 (37.1)	1569 (39.0)
Below bachelor	113 (68.1)	2195 (60.6)	149 (62.9)	2457 (61.0)
Prenatal factors				
Number of prenatal tests*, mean±SD	8.6±2.7	9.2±2.4	9.5±2.5	9.2±2.4
Maternal active smoking, n (%)				
Yes	0 (0.0)	5 (0.1)	0 (0.0)	5 (0.1)
No	166 (100)	3618 (99.9)	237 (100)	4021 (99.9)
Maternal passive smoking, n (%)				
Yes	4 (2.4)	62 (1.7)	2 (0.8)	68 (1.7)
No	162 (97.6)	3561 (98.3)	235 (99.2)	3958 (98.3)
Perinatal factors				
Gender*, n (%)				
Male	85 (51.2)	2008 (55.4)	153 (64.6)	2246 (55.8)
Female	81 (48.8)	1615 (44.6)	84 (35.4)	1780 (44.2)
Birth length* (cm), mean±SD	45.9±2.3	50.1±1.5	52.3±1.5	50.1±1.8
Asphyxia neonatorum, n (%)				
Yes	0 (0.0)	7 (0.2)	0 (0.0)	7 (0.2)
No	166 (100.0)	3616 (99.8)	237 (100.0)	4019 (99.8)
Mode of delivery*, n (%)				
Natural	57 (34.3)	898 (24.8)	23 (9.7)	978 (24.3)
Caesarean	109 (65.7)	2725 (75.2)	214 (90.3)	3048 (75.7)

*P<0.05.

LBW, low birth weight; NBW, normal birth weight.

adaptability (aOR 1.56, 95% CI 1.06 to 2.31). LBW has no significant effects on neurodevelopmental delay in language and social behaviour. Macrosomia also has no significant effects on clinical diagnosis of neurodevelopmental delay in all domains.

DISCUSSION

This study examined the impact of BW on neurodevelopment of infants at age 1–6 months. The findings indicated that LBW is negatively associated with DQ in all neurological domains, and LBW increases the risk of 'neurodevelopmental delay' in gross motor, fine motor and adaptability. Macrosomia is also associated with DQ in all neurological domains; however, macrosomia has no significant impact on neurodevelopmental delay. The

results of this study are consistent with previous studies conducted in developed countries.^{27 28}

It is well documented that LBW results in a series of health problems both at the early stage of infancy and in adulthood.^{29 30} However, the impact of LBW on neurodevelopment at an early age is less investigated³¹ and has drawn inconsistent conclusion with various limitations. Chan and colleagues³² reported that abnormal neural pathways and brain growth retardation may result in higher rates of delayed neurodevelopment in LBW, especially in terms of gross motor and fine motor performance. Other study that evaluated the impact of small for gestational age on behavioural development also suggested that small for gestational age is negatively associated with some attentional problems and aggressive behaviours in a

Table 2 Associations between birth weight and DQ of infants by different neurodevelopmental domains

	DQ (mean±SD)	P ₁ value	B	95% CI for B	P ₂ value
Gross motor DQ	101.0±23.0				
NBW	101.7±22.5	<0.001	0		
LBW	82.1±25.9		-11.18	-11.36 to -10.99	<0.001
Macrosomia	104.4±21.9		0.49	0.36 to 0.63	<0.001
Fine motor DQ	107.2±29.9				
NBW	108.0±29.7	<0.001	0		
LBW	86.8±27.6		-6.57	-6.76 to -6.39	<0.001
Macrosomia	109.7±28.3		-2.73	-2.87 to -2.59	<0.001
Adaptability DQ	85.5±22.3				
NBW	85.9±22.2	<0.001	0		
LBW	76.6±23.5		-4.87	-5.05 to -4.68	<0.001
Macrosomia	85.7±21.8		-1.19	-1.33 to -1.05	<0.001
Language DQ	86.7±21.4				
NBW	87.0±21.2	<0.001	0		
LBW	78.2±23.6		-6.23	-6.42 to -6.05	<0.001
Macrosomia	88.1±22.2		0.43	0.29 to 0.57	<0.001
Social behaviour DQ	87.8±22.3				
NBW	88.1±22.0	<0.001	0		
LBW	77.6±25.0		-6.82	-7.0 to -6.64	<0.001
Macrosomia	90.3±22.5		1.10	0.96 to 1.24	<0.001

P₁, one-way analysis of variance; P₂, generalised linear model analysis, adjusted for prenatal factors (maternal active and passive smoking, and number of pregnancy tests), perinatal factors (gender of infants, delivery mode, asphyxia neonatorum and birth length) and maternal demographic factors (gestational weeks and education level of parents). DQ, development quotient; LBW, low birth weight; NBW, normal birth weight.

school-age child.³³ However, a study conducted by Ballot and colleagues,³⁴ using the Bayley Scales of Infant Development, showed that LBW infants are more likely to have abnormal development outcomes in cognitive, motor and language subscales. The inconsistencies of these results may be related to the use of different indicators related to BW and different scales to assess neurodevelopment, timing of assessment and adjustment variables.

In the present study, we found that LBW primarily affects neurodevelopmental delay in gross motor, fine motor and adaptability during the early stage of infancy, which is different from a previous study, and may suggest LBW has different mechanisms for different types of neurodevelopmental delay.³⁵ The sequence in which gross and fine motor skills are acquired does not vary during the early stage of child development, but the pace of acquisition differs from child to child. The results of the present study may also suggest that the onset of gross and fine motor development can be affected by LBW. Motor performance is mainly influenced by the maturation and plasticity of the brain motor system; thus, LBW influences motor skills mainly through its effect on motor system maturation and plasticity.³⁶ Additionally, a poorer development of adaptability among LBW infants during the early stage of child development may also suggest

there is neurodevelopmental damage associated with adaptability of the brain.

In this study, there was no significant difference between BW and neurodevelopmental delay in infants' language and social behaviours, which conflicts with a previous study.³⁷ This inconsistency may be associated with the physiological age of neurodevelopment assessment. In the present study, we assessed neurodevelopment at age 1–6 months, in which the auditory function of infants, which plays a decisive role in language development,³⁸ is not fully developed. In addition, the Chinese version of GDS rarely has test items for language and social behaviour for infants at age 1–6 months, which may also have certain impact on the test results. With an increase in age, there must be more items that can detect and accurately reflect infant language and social behaviour development.

Of note, in the present study, LBW does not have significant impact on language and social behaviour development among infants, which does not mean those aspects will not have an impact in the future if no effective interventions are taken.³⁹ This is because neurodevelopment has specific processes, and these domains are interdependent, that is, each one influences and is influenced by the others. Motor behaviour favours children's experiences in acting and interacting, providing them with concrete

**Table 3** Association of birth weight with neurodevelopmental diagnosis by different neurodevelopmental domains*

	Neurodevelopmental delay, n (%)	Wald χ^2	P value	OR	95% CI for OR
Gross motor					
NBW	792 (21.9)	Reference			
LBW	93 (56.0)	19.95	<0.001	2.43	1.65 to 3.60
Macrosomia	44 (18.6)	0.07	0.792	0.95	0.67 to 1.36
Fine motor					
NBW	974 (26.9)	Reference			
LBW	93 (56.0)	4.01	0.045	1.49	1.01 to 2.19
Macrosomia	54 (22.8)	0.04	0.839	1.03	0.74 to 1.44
Adaptability					
NBW	2038 (56.3)	Reference			
LBW	113 (68.1)	5.00	0.025	1.56	1.06 to 2.31
Macrosomia	136 (57.4)	0.02	0.891	1.02	0.77 to 1.35
Language					
NBW	1929 (53.2)	Reference			
LBW	100 (60.2)	2.60	0.107	1.37	0.94 to 2.00
Macrosomia	121 (51.1)	0.58	0.448	0.90	0.68 to 1.19
Social behaviour					
NBW	1844 (50.9)	Reference			
LBW	91 (54.8)	1.25	0.264	1.24	0.85 to 1.79
Macrosomia	113 (47.7)	0.91	0.339	0.87	0.66 to 1.15

*Adjusted for prenatal factors (maternal active and passive smoking, and number of pregnancy tests), perinatal factors (gender of infants, delivery mode, asphyxia neonatorum and birth length) and maternal demographic factors (gestational weeks and education level of parents). LBW, low birth weight; NBW, normal birth weight.

opportunities that favour the development in perceptual, cognitive, linguistic, adaptive and social areas. Therefore, motor neurodevelopmental delay may reflex on all areas of child development.⁴⁰ However, from another perspective, targeted interventions in the early stages of neurodevelopmental delay will achieve the greatest benefits.⁴¹

The present study has not found a significant correlation between macrosomia and neurological diagnosis, echoing previous studies. Some previous studies have suggested that the adaptability of a 6-month-old with macrosomia lags behind that of an NBW infant, and this difference still exists at 12 months.^{42 43} It should be mentioned that the mechanisms and impact of LBW and macrosomia on neurodevelopment may be different. Therefore, the impact and mechanism of macrosomia on neurodevelopment need to be validated and examined in future studies.

Strengths and limitations

The main strength of this study was the use of a perspective cohort which provided detailed data collected from pregnancy through 6-month-old newborns, thus allowing for multiple risk factors analysis of infants' neurodevelopment. Additionally, developing countries have specific socioeconomic and cultural factors, as shown by this

study's sample, such as lower obesity rate, higher caesarean section rate and lower smoking rate, all of which allow for adjustment for a wide range of risk factors that may be associated with infants' neurodevelopment. Thus, the results of this study are of great value to policy makers to guide and implement intervention programmes aimed at improving infants' neurodevelopment in developing countries.

There are some limitations to this study. First, we do not have data on neurodevelopment after 6 months of age, which are required to further observe the effects of BW on long-term neurodevelopment. Second, there are only few items that assess neurodevelopment of infants aged 1–6 months in the revised GDS, and this led to less sensitive assessment results. It is unwise to reflect on infants' developmental pattern with only one assessment result⁴³; however, the revised GDS is widely used for neurodevelopmental assessment and diagnosis in China. Additionally, the associations of BW with DQ are not in line with the associations of BW with clinical diagnosis of neurodevelopmental delay, which may suggest the norm of GDS at early stage of infancy needs revision. Third, the revised GDS is not commonly used in Western countries, making the comparison of the association of BW with

neurodevelopment among different studies difficult. Therefore, further studies are warranted to determine whether and to what extent BW has an impact on the neurodevelopment of a child.

CONCLUSION

In conclusion, by studying the relationship between neurodevelopmental status and BW among infants aged 1–6 months in the WHBC, we could conclude that both LBW and macrosomia are associated with DQ in infants, and LBW increases the risk of a diagnosis of ‘neurodevelopment delay’. The risks involved gross and fine motors and adaptability in babies. Further studies are warranted to determine whether, to what extent and how BW affects the neurodevelopment of a child.

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Contributors TJ, YY and MMG conceived the study idea. MZ and YRC performed the literature search. ZC, MZ and BZ were involved in data collection. MZ wrote the first draft of the manuscript. MMG and TJ critically revised the manuscript. All authors approved the final version of the manuscript. TJ had full access to all of the data (including statistical reports and tables) in the study, and takes responsibility for the integrity of the data and the accuracy of the data analysis.

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Competing interests None declared.

Patient consent for publication Not required.

Ethics approval The WHBC study was approved by the Institutional Review Board of Women and Children's Hospital of Wuhan (no 2010009), and written informed consent was obtained from participants' parents before recruitment. The present study was approved by the Review Board of Guangzhou Medical College (no [2015]17).

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available upon reasonable request. All of the de-identified individual participant data used in this study can be shared with investigators by contacting the corresponding author. Other data of the WHBC study are available (including data dictionaries) for investigators whose proposed use of the data has been approved by an independent review committee identified for this purpose by contacting the WHBC study team.

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