https://doi.org/10.53339/aimdr.2025.11.1.4
E-ISSN: 2395-2822 | P-ISSN: 2395-2814

Renal development and functional outcomes: A comparative study of term low birth weight and normal birth weight infants

Mohammed Jafar Iqbal, Mirza Md. Ziaul Islam, Atiqul Islam, Tanusree Sen

Department of Pediatric Infectious Diseases and Community Pediatrics, Bangladesh Shishu Hospital and Institute, Dhaka, Bangladesh

Address for correspondence: Mohammed Jafar Iqbal, Department of Pediatric Infectious Diseases and Community Pediatrics, Bangladesh Shishu Hospital and Institute, Dhaka, Bangladesh. E-mail: drrubel1234@gmail.com

Abstract

Introduction: One of the biggest issues facing emerging nations is low birth weight (LBW). In our situation, the term LBW may be caused by maternal malnourishment, inadequate prenatal care, low socioeconomic position, repeated pregnancies with close spacing, and a lack of health knowledge. The proper renal development of LBW newborns resulting from intrauterine growth retardation is negatively impacted. Renal functional maturity can be predicted by examining the link between renal function and volume. The aim of this study was to compare the renal volume and functional status in the term LBW versus term normal birth weight (NBW) babies at 1 year.

Materials and Methods: This case–control study was conducted at the Department of Pediatric Infectious Disease and Community Pediatrics at Bangladesh Shishu Hospital and Institute, Dhaka, from June 2009 to May 2010. Patients were selected according to inclusion and exclusion criteria. 100 children were recruited in this study at 1 year of age from that hospital. Among them 50 were born at term with NBW and the rest 50 were born at term with LBW. Data were collected by developing a structured questionnaire and a statistical analysis was carried out by using the Statistical Package for Social "IBM SPSS Statistics for Windows, version IBM SPSS Statistics for Windows, version XXII (IBM V.22).

Result: It was observed that almost two-thirds (62.0%) of subjects belonged to age 12 months in the term NBW and 28 (56.0%) in the term LBW. The mean age was 11.9 ± 0.6 months in the term NBW and 12.2 ± 0.7 months in the term LBW. More than half (58.0%) of subjects were male in the term NBW and 22 (44.0%) in the term LBW. The majority (88.0%) of subjects came from urban areas in the term NBW and 37 (74.0%) in the term LBW. The mean gestational age was 39.1 ± 0.8 weeks in the term NBW and 37.7 ± 0.8 weeks in the term LBW. The mean SBP was 86.6 ± 8.0 mmHg in the term NBW and 92.4 ± 7.9 mmHg in the term LBW. The mean diastolic blood pressure was 49.2 ± 4.3 mmHg in the term NBW and 52.2 ± 4.7 mmHg in the term LBW. The mean creatinine was 0.5 ± 0.13 mg/dL in the term NBW and 0.53 ± 0.12 mg/dL in the term LBW. The mean spot urine protein creatinine ratio was 0.3 ± 0.06 in the term NBW and 0.4 ± 0.07 in the term LBW. The mean glomerular filtration rate (GFR) was 72.8 ± 19.1 mL/min/1.73 m^2 in the term NBW and 66.4 ± 16.7 mL/min/1.73 m^2 in the term LBW. The mean kidney length was 5.5 ± 0.3 in the term NBW and 5.3 ± 0.3 in the term LBW. The mean breadth was 4.3 ± 0.2 in the term NBW and 4.0 ± 0.1 in the term LBW. The mean thickness was 2.2 ± 0.2 in the term NBW and 2.0 ± 0.3 in the term LBW. The mean kidney volume was 27.4 ± 3.7 cm^3 in the term NBW and 22.9 ± 3.6 cm^3 in the term LBW. In the male group, the mean kidney volume was 28.1 ± 3.9 cm^3 in the term NBW and 22.4 ± 2.7 cm^3 in the term LBW. In the female group, the mean kidney volume was 26.5 ± 3.3 cm^3 in the term NBW and 23.4 ± 4.2 cm^3 in the term LBW. In the male group, the mean estimated GFR was 75.2 ± 17.9 mL/min/1.73 m^2 in the term NBW and 67.1 ± 15.6 mL/min/1.73 m^2 in the term LBW. In the female group, the mean estimated GFR was 69.3 ± 20.6 mL/min/1.73 m^2 in the term NBW and 65.8 ± 17.8 mL/min/1.73 m^2 in the term LBW.

Conclusion: This study demonstrates that blood pressure and spot urine protein creatinine ratio were significantly elevated in LBW babies. Kidney length (D1), breadth (D2), and thickness (D3) were smaller in LBW babies. LBW can potentially lead to adverse effects on kidney size and function in children.

Keywords: Low birth weight, normal birth weight, renal volume.

Introduction

According to Lee *et al*. (2014), kidney size is a crucial metric for both assessing children with renal disorders and determining appropriate organ growth.[1] Early-life factors, such as the mother's age and nutritional state during pregnancy, are known to affect body composition, growth patterns, and the likelihood of developing chronic non-communicable diseases later in life.[2] Nephrons, the structural and functional building blocks of the kidneys, have a number that can be estimated from kidney size. Smaller nephrons result from inadequate kidney growth and development in fetal life since the number of nephrons is mostly regulated in prenatal life.[3] According to some research, pre-term kids, have short for gestational age (SGA), have smaller kidneys with fewer nephrons, and have retarded growth.[2,4] 60% of nephrons form in the third trimester and have formed by 36 weeks of gestation, although cellular proliferation in practically all organs occurs mostly before the third trimester of normal pregnancies.[5,6] Research has shown that the term Low birth weight (LBW) is a separate risk factor for the development of adult-onset diabetes mellitus, hypertension, and renal disorders.[7,8] The development of the fetal kidney starts at 9 weeks and ends at 36 weeks. It is important to remember that at term gestation, no additional nephrons emerge after birth. LBW, pre-term, low kidney mass and volume, and gene polymorphisms are risk factors for low nephron mass and/or kidney disease.[2] Pre-maturity or intrauterine growth retardation may be the secondary cause of LBW. Weight for gestational age is a significant independent predictor of kidney size at delivery and in the 1st few months of life.[9] In addition, research has shown that term neonates with LBW can achieve comparable glomerular filtration rates (GFRs) to neonates with normal birth weight (NBW), even if their kidney volumes are 25% lower in the 1st week of life.[10] Fetal growth restriction and a permanent nephron deficit of up to 30% are caused by poor maternal nutrition (such as low protein intake and vitamin A deficiency), reduced placenta perfusion, or steroid administration in late pregnancy. Previous studies have reported a 50% reduction in the GFR in these situations.[3,6] LBW may hurt a child's kidney size and function. For both term LBW and term NBW children, it is important to understand the typical ranges of the kidney's volume and function of the body surface area.[6] According to studies conducted by Hughson *et al*. (2006) and Berglund *et al*. (2014), there is a correlation between term LBW, SGA, and pre-term and a higher risk of albuminuria, hypertension, chronic renal disease, and kidney failure.[11,12] As a stand-in, kidney size has been employed, and in fact, variations in kidney volume in children and young adults have been linked to birth weight.[13,14] The link between kidney function and kidney volume in infants born before full term and up to late infancy a critical and dynamic period of renal functional maturity is poorly understood. According to Bagby (2009), continuous monitoring of GFR is crucial for high-risk infants based on essential criteria including birth weight and gestational age.[15] The critical problem of nephron protection at birth must be prioritized. Considering the mentioned facts and figures, the present study is aimed to compare the renal volume and functional status in the term low weight versus term NBW babies at 1 year.

Materials and Methods

This case–control study was conducted at the Department of Pediatric Infectious Diseases and Community Pediatrics at Bangladesh Shishu Hospital and Institute, Dhaka, from June 2009

to May 2010. Patients were selected according to inclusion and exclusion criteria. 100 children were recruited in this study at 1 year of age from that hospital. Among them 50 were born at term with NBW and the rest 50 were born at term with LBW. Term LBW babies of 1 year of age (weight: <2.5 kg), and Term NBW babies of 1 year of age (weight: >2.5 kg) were included among the inclusion criteria. History of severe perinatal asphyxia, severe sepsis, intrauterine infections, and any congenital anomalies were excluded from the study. Data were collected by developing a structured questionnaire and a statistical analysis was carried out by using the Statistical Package for Social "IBM SPSS Statistics for Windows, version XXII (IBM Corp., Armonk, N.Y., USA)."

Results

Table 1 shows the distributions of the study subjects by participants' characteristics. It was observed that almost two-thirds (62.0%) of subjects belonged to age 12 months in the term NBW and 28(56.0%) in the term LBW. The mean age was 11.9 ± 0.6 months in the term NBW and 12.2 ± 0.7 months in the term LBW. More than half (58.0%) of subjects were male in the term NBW and 22 (44.0%) in the term LBW. The majority (88.0%) of subjects came from urban areas in the term NBW and 37 (74.0%) in the term LBW. The difference was statistically not significant ($P > 0.05$) between the two groups. The mean gestational age was 39.1 ± 0.8 weeks in the term NBW and 37.7 ± 0.8 weeks in the term LBW. The difference was statistically significant ($P < 0.05$) between the two groups.

Table 1: Distributions of the study subject by participants characteristics (n=100)

Participants characteristics	Term NBW (n=50)		Term LBW (n=50)		*P*-value
	n	%	*n*	%	
Distribution according to age (in months)					
11	11	22.0	7	14.0	[a]0.087[ns]
12	31	62.0	28	56.0	
13	8	16.0	15	30.0	
Mean±SD	11.9±0.6		12.2±0.7		
Range (min-max)	11–13		11–13		
Distribution according to gender					
Male	29	58.0	22	44.0	[b]0.161[ns]
Female	21	42.0	28	56.0	
Distribution according to residence					
Urban	44	88.0	37	74.0	[b]0.074[ns]
Rural	6	12.0	13	26.0	
Distribution according to gestational age (weeks)					
Mean±SD	39.1±0.8		37.7±0.8		0.001[s]

ns: Not significant, [a]*P*-value reached from the Unpaired t-test, [b]*P*-value reached from the Chi-square test, s: Significant, *P*-value reached from Unpaired t-test, LBW: Low birth weight, NBW: Normal birth weight

Table 2: Distributions of the study subject by anthropometry parameter (n=100)

Anthropometry parameter	Term NBW (n=50)	Term LBW (n=50)	*P*-value
	Mean±SD	Mean±SD	
Length (cm)	75.8±0.9	73.5±0.8	0.001[s]
Range (min-max)	74.1–76.9	72.0–75	
Weight (kg)	9.2±0.7	8.0±0.8	0.001[s]
Range (min-max)	8.0–10.5	6.5–9.4	
BMI (kg/m2)	15.9±1.3	14.9±1.6	0.001[s]
Range (min-max)	13.8–18.7	12.2–18.1	

s: Significant, *P*-value reached from the Unpaired-t-test, LBW: Low birth weight, NBW: Normal birth weight

Table 3: Distributions of the study subject by blood pressure (n=100)

Blood pressure (mmHg)	Term NBW (n=50)	Term LBW (n=50)	*P*-value
	Mean±SD	Mean±SD	
Systolic blood pressure (mmHg)	86.6±8.0	92.4±7.9	0.001[s]
Range (min-max)	70–95	75–100	
Diastolic blood pressure (mmHg)	49.2±4.3	52.2±4.7	0.001[s]
Range (min-max)	40–55	45–60	

s: Significant, *P*-value reached from Unpaired t-test, LBW: Low birth weight, NBW: Normal birth weight

Table 4: Distributions of the study subject by renal function test (*n*=100)

Renal function test	Term NBW (*n*=50) Mean±SD	Term LBW (*n*=50) Mean±SD	*P*-value
Creatinine (mg/dL)	0.5±0.13	0.53±0.12	0.282ns
Range (min-max)	0.3–0.7	0.33–0.72	
Spot urine protein creatinine ratio	0.3±0.06	0.4±0.07	0.001s
Range (min-max)	0.2–0.39	0.25–0.48	
Glomerular filtration rate (mL/min/1.73 m^2)	72.8±19.1	66.4±16.7	0.079ns
Range (min-max)	49.5–112.7	46.1–102.3	

s: Significant, ns: Not significant, *P*-value reached from Unpaired t-test, LBW: Low birth weight, NBW: Normal birth weight

Table 5: Distributions of the study subject by ultrasonogram of the kidney (*n*=100)

Ultrasonogram of kidney	Term NBW (*n*=50) Mean±SD	Term LBW (*n*=50) Mean±SD	*P*-value
Kidney length (D1)	5.5±0.3	5.3±0.3	0.001s
Range (min-max)	5.0–6.1	4.9–6.0	
Breadth (D2)	4.3±0.2	4.0±0.1	0.001s
Range (min-max)	4–4.6	3.8–4.3	
Thickness (D3)	2.2±0.2	2.0±0.3	0.001s
Range (min-max)	1.8–2.6	1.6–2.6	
Kidney volume (cm^3)	27.4±3.7	22.9±3.6	0.001s
Range (min-max)	20.5–35.7	17.3–34.5	

s: Significant, *P*-value reached from Unpaired t-test, LBW: Low birth weight, NBW: Normal birth weight

The mean length was 75.8 ± 0.9 cm in the term NBW and 73.5 ± 0.8 cm in the term LBW. The mean weight was 9.2 ± 0.7 kg in the term NBW and 8.0 ± 0.8 kg in the term LBW. The mean BMI was 15.9 ± 1.3 kg/m^2 in the term NBW and 14.9 ± 1.6 kg/m^2 in the term LBW. The difference was statistically significant ($P < 0.05$) between the two groups [Table 2].

The mean systolic blood pressure (SBP) was 86.6 ± 8.0 mmHg in the term NBW and 92.4 ± 7.9 mmHg in the term LBW. The mean diastolic blood pressure (DBP) was 49.2 ± 4.3 mmHg in the term NBW and 52.2 ± 4.7 mmHg in the term LBW. The difference was statistically significant ($P < 0.05$) between the two groups [Table 3].

Table 6: Kidney volume of children and estimated GFR by birth weight status and sex (*n*=100)

Kidney volume, cm^3					
Sex	Term NBW		Term LBW		*P*-value
	n	Mean±SD	*n*	Mean±SD	
Male	29	28.1±3.9	22	22.4±2.7	0.001s
Female	21	26.5±3.3	28	23.4±4.2	0.008s
Estimated glomerular filtration rate (mL/min/1.73 m^2)					
Male	29	75.2±17.9	22	67.1±15.6	0.099ns
Female	21	69.3±20.6	28	65.8±17.8	0.524ns

s: Significant, *P*-value reached from Unpaired t-test, LBW: Low birth weight, NBW: Normal birth weight, GFR: Glomerular filtration rate

The mean creatinine was 0.5 ± 0.13 mg/dL in the term NBW and 0.53 ± 0.12 mg/dL in the term LBW. The difference in Creatinine was not statistically significant ($P > 0.05$) between the two groups.

The mean spot urine protein creatinine ratio was 0.3 ± 0.06 in the term NBW and 0.4 ± 0.07 in the term LBW. The difference in spot urine protein creatinine ratio was statistically significant ($P < 0.05$) between the two groups. The mean GFR was 72.8 ± 19.1 mL/min/1.73 m^2 in the term NBW and 66.4 ± 16.7 mL/min/1.73 m^2 in the term LBW. The difference in GFR was not statistically significant ($P > 0.05$) between the two groups [Table 4].

The mean kidney length was 5.5 ± 0.3 in the term NBW and 5.3 ± 0.3 in the term LBW. The mean breadth was 4.3 ± 0.2 in the term NBW and 4.0 ± 0.1 in the term LBW. The mean thickness was 2.2 ± 0.2 in the term NBW and 2.0 ± 0.3 in the term LBW. The mean kidney volume was 27.4 ± 3.7 cm^3 in the term NBW and 22.9 ± 3.6 cm^3 in the term LBW. The difference was statistically significant ($P < 0.05$) between the two groups [Table 5].

In the male group, the mean kidney volume was 28.1 ± 3.9 cm^3 in the term NBW and 22.4 ± 2.7 cm^3

in the term LBW. In the female group, the mean kidney volume was 26.5 ± 3.3 cm^3 in the term NBW and 23.4 ± 4.2 cm^3 in the term LBW. The difference was statistically significant ($P < 0.05$) between the two groups. In the male group, the mean estimated GFR (eGFR) was 75.2 ± 17.9 mL/min/1.73 m^2 in the term NBW and 67.1 ± 15.6 mL/min/1.73 m^2 in the term LBW. In the female group, the mean eGFR was 69.3 ± 20.6 mL/min/1.73 m^2 in the term NBW and 65.8 ± 17.8 mL/min/1.73 m^2 in the term LBW. The difference was statistically not significant ($P > 0.05$) between the two groups [Table 6].

Discussion

In the present study, the mean age was 11.9 ± 0.6 months in the term NBW and 12.2 ± 0.7 months in the term LBW. The mean age difference was almost similar between the term NBW and the term LBW. Similarly, higher age and age ranges were also observed by Gilarska *et al*. (2019), Park *et al*. (2019), and Kaze *et al*. (2020).[16-18] In the current study it was observed that 42.0% of subjects were female in the term NBW and 56.0% in the term LBW, which indicates that the term LBW was more common in female than in male children. A study by Ferdous *et al*. (2018) found that 57.2% and 42.8% were female and male, respectively, in the term LBW.[6] Considering residence in the current study it was observed that 88.0% of subjects came from urban areas in the term NBW and 74.0% in the term LBW. Bener *et al*.'s (2012) study found that 83.9% of subjects were in urban areas in the term LBW and 85.4% in the term NBW.[19] However, the mean gestational age of this study was 39.1 ± 0.8 weeks in the term NBW and 37.7 ± 0.8 weeks in the term LBW. It was significantly ($P < 0.05$) higher in the term NBW. Whereas, Ferdous *et al*. (2018) study found that the gestational age at birth was significantly lower in the term LBW than in the term NBW children.[6] It was also observed from this study that the mean length was 75.8 ± 0.9 cm in the term NBW and 73.5 ± 0.8 cm in the term LBW, the mean weight was 9.2 ± 0.7 kg in the term NBW and 8.0 ± 0.8 kg in the term LBW and the mean BMI was 15.9 ± 1.3 kg/m^2 in the term NBW and 14.9 ± 1.6 kg/m^2 in the term LBW. The mean values for length, weight, and BSA were significantly ($P < 0.05$) lower in the term LBW children than in the term NBW children. Ferdous *et al*. (2018) study observed similar results. While considering blood pressure in the current study it was observed that the mean SBP was 86.6 ± 8.0 mmHg in the term NBW and 92.4 ± 7.9 mmHg in the term LBW. The mean DBP was 49.2 ± 4.3 mmHg in the term NBW and 52.2 ± 4.7 mmHg in the term LBW. The mean difference in blood pressure was significantly ($P < 0.05$) higher in the term LBW group.[6] Lillas *et al*. (2021) also obtained in their study that the group with the term LBW had higher blood pressure as compared with those in the term NBW group, which is similar to the present study.[20] Moreover, in the present study, it was found that the mean creatinine was 0.5 ± 0.13 mg/dL in the term NBW and 0.53 ± 0.12 mg/dL in the term LBW, with no statistically significant ($P > 0.05$) difference was observed between term NBW and term LBW. The mean GFR was 72.8 ± 19.1 mL/min/1.73 m^2 in the term NBW and 66.4 ± 16.7 mL/min/1.73 m^2 in the term LBW. The mean GFR was higher in NBW but the difference was not statistically significant ($P > 0.05$) between term NBW and term LBW. The mean spot urine protein creatinine ratio was 0.3 ± 0.06 in the term NBW and 0.4 ± 0.07 in the term LBW. The mean spot urine protein creatinine ratio was significantly ($P < 0.05$) higher in the term LBW. Ferdous *et al*. (2018) study found the mean eGFR was lower in the term LBW children than in the NBW children 61.8 ± 12.8 mL/min/1.73 m^2 and 67.4 ± 16.0 mL/min/1.73 m^2, respectively, which is comparable with the present study.[6] Similarly, Gilarska *et al*. (2019) study also found the mean GFR was lesser in the term LBW babies compared to NBW babies. The mean kidney length was found 5.5 ± 0.3 in the term NBW and 5.3 ± 0.3 in the term LBW in this study. Term LBW babies had significantly ($P < 0.05$) a smaller kidney length (D1) than that of the NBW babies. Gilarska *et al*. (2019) study identified that kidney length <85.0% of normal value was found in 12.7% of term LBW babies and 5.8% of NBW babies. Kidney length was shorter in the group of term LBW-born babies.

In this study, it was observed that the mean breadth was 4.3 ± 0.2 in the term NBW and 4.0 ± 0.1 in the term LBW. The mean thickness was 2.2 ± 0.2 in the term NBW and 2.0 ± 0.3 in the term LBW. The mean breadth and thickness were significantly ($P < 0.05$) lesser in the term LBW babies. The mean kidney volume in the current study was 27.4 ± 3.7 cm^3 in the term NBW and 22.9 ± 3.6 cm^3 in the term LBW. The mean kidney volume was significantly ($P < 0.05$) smaller in the term LBW babies.[16] Ferdous *et al*. (2018) study showed that the term LBW children had a smaller kidney volume than that of the NBW children.[6] Kandasamy *et al*. (2012) reported that within 6 days of birth, term LBW infants, achieved a similar GFR to NBW infants, despite 25.0% smaller kidney volumes.[10] The above findings support the present study. In the present study it was observed that in the male group, the mean kidney volume was 28.1 ± 3.9 cm^3 in the term NBW and 22.4 ± 2.7 cm^3 in the term LBW. In the female group, the mean kidney volume was 26.5 ± 3.3 cm^3 in the term NBW and 23.4 ± 4.2 cm^3 in the term LBW. The mean kidney volume was significantly ($P < 0.05$) elevated in the term NBW compared to the term LBW in both sexes. Ferdous *et al*. (2018) study found that male children having term LBW had a smaller average kidney volume/BSA than male children having NBW. However, no significant change was found in kidney volume/BSA between female children having the term LBW and those having the term NBW.[6] In addition, it was observed in the current study that in the male group, the mean eGFR was 75.2 ± 17.9 mL/min/1.73 m^2 in the term NBW and 67.1 ± 15.6 mL/min/1.73 m^2 in the term LBW. In the female group, the mean eGFR was 69.3 ± 20.6 mL/min/1.73 m^2 in the term NBW and 65.8 ± 17.8 mL/min/1.73 m^2 in the term LBW. The mean eGFR of both sexes was higher in NBW but the difference was not statistically significant ($P > 0.05$) between the two groups. Ferdous *et al*. (2018) study showed the mean eGFR was significantly ($P < 0.05$) higher in the term NBW in both sexes, which differs from the current study.[6] This may be due to the small sample size in the present study. In an earlier study, Lillas *et al*. (2021) showed that the term LBW had a significantly ($P < 0.05$) lower eGFR than the term NBW, which supports the present study.[20]

Limitations of the study

The study was conducted for a very short period in a single hospital with a small sample size. Hence, the results may not represent the whole community. Kidney function was not measured by inulin clearance, which is known to be a direct measure of kidney function. The unavailability of data about maternal and child dietary habits is also a limitation.

Conclusion

This study demonstrates that blood pressure and spot urine protein creatinine ratio were significantly elevated in the term LBW babies. Kidney length (D1), breadth (D2), and thickness (D3) were smaller in the term LBW babies. Term LBW can lead to adverse effects on kidney size in children and act thereby.

Funding

No funding sources.

Conflicts of Interest

None declared.

Ethical Approval

The study was approved by the Institutional Ethics Committee and Ethical clearance was obtained from the ethical board of Bangladesh Shishu Hospital and Institute, Dhaka.

Recommendation

More studies differentiating cortex and medulla, as well as studies including kidney histology, are needed. Enough precaution is recommended to prevent term LBW.

References

1. Lee MJ, Son MK, Kwak BO, Park HW, Chung S, Kim KS. Kidney size estimation in Korean children with

Technesium-99m dimercaptosuccinic acid scintigraphy. Korean J Pediatr 2014;57:41-5.

2. Luyckx VA, Bertram JF, Brenner BM, Fall C, Hoy WE, Ozanne SE, *et al*. Effect of fetal and child health on kidney development and long-term risk of hypertension and kidney disease. Lancet 2013;382:273-83.
3. Geelhoed JM, Verburg BO, Nauta J, Lequin M, Hofman A, Moll HA, *et al*. Tracking and determinants of kidney size from fetal life until the age of 2 years: The Generation R Study. Am J Kidney Dis 2009;53:248-58.
4. Abitbol CL, DeFreitas MJ, Strauss J. Assessment of kidney function in preterm infants: Lifelong implications. Pediatr Nephrol 2016;31:2213-22.
5. Hughson M, Farris AB 3rd, Douglas-Denton R, Hoy WE, Bertram JF. Glomerular number and size in autopsy kidneys: The relationship to birth weight. Kidney Int 2003;63:2113-22.
6. Ferdous F, Ma E, Raqib R, Wagatsuma Y. Birth weight influences the kidney size and function of Bangladeshi children. J Dev Orig Health Dis 2018;9:386-94.
7. White SL, Perkovic V, Cass A, Chang CL, Poulter NR, Spector T, *et al*. Is low birth weight an antecedent of CKD in later life? A systematic review of observational studies. Am J Kidney Dis 2009;54:248-61.
8. Keijzer-Veen MG, Kleinveld HA, Lequin MH, Dekker FW, Nauta J, de Rijke YB, *et al*. Renal function and size at young adult age after intrauterine growth restriction and very premature birth. Am J Kidney Dis 2007;50:542-51.
9. Schmidt ID, Chellakooty M, Boisen KA, Damgaard ID, Kai CM, Olgaard K, *et al*. Impaired kidney growth in low-birth-weight children: Distinct effects of maturity and weight for gestational age. Kidney Int 2005;68:731-40.
10. Kandasamy Y, Smith R, Wright IM, Lumbers ER. Relationships between glomerular filtration rate and kidney volume in low-birth-weight neonates. J Nephrol 2012;26:894-8.
11. Hughson MD, Douglas-Denton R, Bertram JF, Hoy WE. Hypertension, glomerular number, and birth weight in African Americans and white subjects in the southeastern United States. Kidney Int 2006;69:671-8.
12. Berglund D, MacDonald D, Jackson S, Spong R, Issa N, Kukla A, *et al*. Low birthweight and risk of albuminuria in living kidney donors. Clin Transplant 2014;28:361-7.
13. Keijzer-Veen MG, Devos AS, Meradji M, Dekker FW, Nauta J, van der Heijden BJ. Reduced renal length and volume 20 years after very preterm birth. Pediatr Nephrol 2010;25:499-507.
14. Sanderson KR, Chang E, Bjornstad E, Hogan SL, Hu Y, Askenazi D, *et al*. Albuminuria, hypertension, and reduced kidney volumes in adolescents born extremely premature. Front Pediatr 2020;8:230.
15. Bagby SP. Developmental origins of renal disease: Should nephron protection begin at birth? Clin J Am Soc Nephrol 2009;4:10-3.
16. Gilarska M, Raaijmakers A, Zhang ZY, Staessen JA, Levtchenko E, Klimek M, *et al*. Extremely low birth weight predisposes to impaired renal health: A pooled analysis. Kidney Blood Press Res 2019;44:897-906.
17. Park B, Lee JW, Kim HS, Park EA, Cho SJ, Park H. Effects of prenatal growth status on subsequent childhood renal function related to high blood pressure. J Korean Med Sci 2019;34:e174.
18. Kaze FF, Nguefack S, Asong CM, Assob JC, Nansseu JR, Kowo MP, *et al*. Birth weight and renal markers in children aged 5–10 years in Cameroon: A cross-sectional study. BMC Nephrol 2020;21:464.
19. Bener A, Salameh KM, Yousafzai MT, Saleh NM. Pattern of maternal complications and low birth weight: Associated risk factors among highly endogamous women. ISRN Obstet Gynecol 2012;2012:540495.
20. Lillas BS, Qvale TH, Richter BK, Vikse BE. Birth weight is associated with kidney size in middle-aged women. Kidney Int Rep 2021;6:2794-802.