Low birth weight is associated with chronic kidney disease only in men

S Li[1], S-C Chen[1], M Shlipak[2], G Bakris[2], PA McCullough[2], J Sowers[2], L Stevens[2], C Jurkovitz[2], S McFarlane[2], K Norris[2], J Vassalotti[2], MJ Klag[2], WW Brown[2], A Narva[2], D Calhoun[2], B Johnson[2], C Obialo[2], A Whaley-Connell[2], B Becker[2] and AJ Collins[1] on behalf of the Kidney Early Evaluation Program Investigators

[1]Chronic Disease Research Group, Minneapolis Medical Research Foundation, Minneapolis, Minnesota, USA and [2]KEEP Steering Committee, National Kidney Foundation, New York, New York, USA

The association of low birth weight and chronic kidney disease was examined in a screened volunteer population by the National Kidney Foundation's Kidney Early Evaluation Program. This is a free, community-based health program enrolling individuals aged 18 years or older with diabetes, hypertension, or a family history of kidney disease, diabetes, or hypertension. Self-reported birth weight was categorized and chronic kidney disease defined as an estimated glomerular filtration rate less than 60 ml per min per 1.73 m^2 or a urine albumin/creatinine ratio $\geqslant$30 mg/g. Among 12 364 participants, 15% reported a birth weight less than 2500 g. In men, significant corresponding odds ratios were found after adjustment for demographic characteristics and health conditions to this low birth weight and chronic kidney disease, but there was no association among women. There was no significant interaction between birth weight and race for either gender. Efforts to clinically understand the etiology of this association and potential means of prevention are essential to improving public health.

Kidney International (2008) **73,** 637–642; doi:10.1038/sj.ki.5002747; published online 19 December 2007

KEYWORDS: birth weight; chronic kidney disease; diabetes; hypertension; nephron

Correspondence: *AJ Collins, Chronic Disease Research Foundation, 914 South 8th Street, Suite S-206, Minneapolis, Minnesota 55404, USA. E-mail: acollins@cdrg.org*

Received 1 August 2007; revised 13 September 2007; accepted 16 October 2007; published online 19 December 2007

Low birth weight has been hypothesized to lead to systemic arterial hypertension and chronic kidney disease (CKD) in adult life.[1,2] Evidence has shown a direct relationship between birth weight and nephron number.[3–6] Some studies showed that birth weight was positively associated with glomerular filtration rate (GFR)[7,8] and negatively associated with serum creatinine level.[7] The association of low birth weight and increased risk of urinary albumin excretion measured by albumin/creatinine ratio (ACR; 30 mg/g or greater) was observed among Pima Indians with type II diabetes mellitus[9] and among Aborigines living in Australia.[10] Finally, the association between low birth weight and end-stage renal disease was confirmed in the southeastern United States[11] and among young adults with diabetes or hypertension in the Medicaid population.[12]

Study samples described in published studies of the association of low birth weight and CKD in adult life are rather small in size or limited to specific racial or ethnic groups. The Kidney Early Evaluation Program (KEEP), conducted by the National Kidney Foundation, is the first national study that targets adult populations at high risk for CKD. KEEP is a free, community-based screening program for CKD, enrolling individuals aged 18 years or older with a personal history of diabetes or hypertension or with a first-degree relative with kidney disease, diabetes, or hypertension. As part of the routine evaluation, participants are asked to recall their birth weights. Since its origin in 1997, KEEP has screened more than 70 000 participants in 48 states. Therefore, a large geographically, racially, and ethnically diverse population is now available to study the association between birth weight and prevalent CKD.

RESULTS

Among the 12 364 eligible KEEP participants included in this study, mean age was 49.1 years (s.d., 13.5); 28.7% were African American and 76.4% female. More than two-thirds of participants reported post-high-school education. Overall, 84.4% had health insurance coverage, 23.2% had been previously diagnosed with diabetes, 48.1% had been told that they had high blood pressure, 16.2% had

cardiovascular disease, and 23.7% had a family member with kidney disease.

The mean reported birth weight was 3195 g (median, 3175; s.d., 781). The distribution of participants in birth-weight categories stratified on gender is presented in Figure 1. The distributions of birth-weight categories within each characteristic are shown in Table 1. The 1845 participants whose birth weight was less than 2500 g were more likely to be African American or female, to have lower educational levels, and to report pre-existing comorbid conditions (diabetes, hypertension, or cardiovascular disease). Participants with high birth weights were more likely to have diabetic mothers.

We tested the interactions between birth weight and gender or race in the associations with CKD. The interaction between birth weight and gender was significant before adjustment for covariates ($P = 0.03$). Therefore, we present the prevalence of each of three kidney disease outcomes by birth-weight categories after gender stratification in Table 2. The prevalence of kidney disease outcomes is also presented for white and African American participants within each gender. By gender, a U-shaped trend was evident for all kidney disease outcomes for men but not for women; men with low birth weight (<2500 g) or high birth weight ($\geqslant 4500$ g) had significantly higher prevalence of each of the three kidney disease outcomes than men with normal birth weight (2500–4499 g). The association of birth weight with kidney disease outcomes was evident for white but not for African American men. However, the three-way interaction among birth weight, gender, and race was not significant.

The interaction between birth weight and gender was still significant after adjustment for age; race; self-reported diabetes, hypertension, or cardiovascular disease; family history of kidney disease; region; education; insurance status; and hypertension control ($P = 0.03$). Adjusted odds ratios of CKD by gender and birth weight are presented in Figure 2 for men and Figure 3 for women. The U-shaped association between birth weight and CKD was still evident for men after controlling for covariates. Compared with men whose birth weight was between 3000 and 3999 g, those whose birth weight was less than 2500 g had 1.65-fold odds (95% confidence interval 1.24–2.20) of CKD and those with birth weight 4500 g and more had 1.41-fold odds (95% confidence interval 1.06–1.88) of CKD. Older age and a history of disease were significantly positively associated with CKD prevalence. Race identified as African American, region other than south, and hypertension control were significantly negatively associated with CKD prevalence.

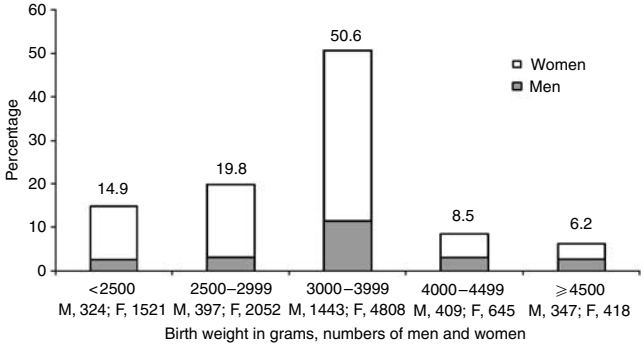

Figure 1 | Distribution of participants in birth-weight categories.

DISCUSSION

In this study, we demonstrate in a large population, aged 18–75 years, with a history of diabetes or hypertension or a family history of diabetes, hypertension, or kidney disease, a U-shaped association between birth-weight categories and several kidney disease outcomes among men but not women. These associations persisted despite multivariable adjustment for several other important kidney disease risk factors, and were similar in further stratifications on race within each gender. These findings are important in better identifying high-risk populations at an early stage in an effort to stem the epidemic of CKD.

In part, our findings showing the association of low and high birth weight with CKD are consistent with prior studies. Our finding of a strong association of low birth weight with kidney disease is consistent with several previous studies.[9–12] Our finding of an association between high birth weight and higher prevalence of CKD is partially consistent with two prior studies.[9,11] Nelson *et al.*[9] found a U-shaped association between birth weight and prevalence of elevated urinary albumin levels defined by ACR 30 mg/g or greater in 308 Pima Indians aged 20–61 years with type II diabetes. In that study, subjects with birth weight <2500 g had a significantly higher risk of ACR 30 mg/g or greater than those with normal birth weight. The association between birth weight $\geqslant 4500$ g and a higher risk of ACR 30 mg/g or greater became insignificant after adjusting for gender, duration of diabetes, HbA1c value, and blood pressure.[9] However, these authors did not find a gender interaction. In a case–control study of the association of birth weight and end-stage renal disease, Lackland *et al.*[11] also found a U-shaped relationship, with the highest odds ratio of renal failure in the lowest birth weight group. There was no association between birth weight $\geqslant 4000$ g and higher prevalence of renal failure in men (odds ratio 1.0). In women, birth weight $\geqslant 4000$ g was associated with a higher risk of renal failure but it was insignificant (odds ratio 1.4, 95% confidence interval 0.8–2.4). However, the association between birth weight $\geqslant 4000$ g and higher risk of renal failure was significant for persons with diabetes as the primary cause of end-stage renal disease (odds ratio 2.4, 95% confidence interval 1.3–4.2).[11]

Researchers have hypothesized potential mechanisms leading to kidney disease in persons with low birth weight.[1,2,13,14] For example, Brenner and Chertow[2] hypothesized that low birth weight due to intrauterine growth retardation or premature birth leads to impaired renal development, which reduces filtration surface area, and therefore leads to systemic glomerular hypertension, further

Table 1 | Characteristics of KEEP participants by birth-weight categories (*N*=12 364)[a]

	Birth weight (g)					
	<2500 *n*=1845	2500–2999 *n*=2449	3000–3999 *n*=6251	4000–4499 *n*=1054	⩾4500 *n*=765	*P*[b]
Age (years)	49.6 ± 13.0	48.9 ± 13.0	48.6 ± 13.6	50.0 ± 14.0	51.8 ± 13.8	0.0135
Race						<0.0001
White	13.9	18.5	51.9	9.6	6.1	
African American	16.7	22.2	47.6	7.2	6.3	
Other race	15.7	20.1	51.0	6.9	6.2	
Gender						<0.0001
Female	16.1	21.7	50.9	6.8	4.4	
Male	11.1	13.6	49.4	14.0	11.9	
Insurance						0.5024
No	16.0	20.3	49.3	8.1	6.3	
Yes	14.7	19.7	50.8	8.6	6.2	
Education						0.0122
⩽12 years	15.7	19.4	49.3	8.4	7.1	
>12 years	14.6	20.0	51.1	8.6	5.8	
Region						0.2635
Northeast	15.9	18.4	50.7	8.7	6.3	
Midwest	14.8	21.9	49.1	8.2	6.0	
South	14.6	19.9	50.5	8.6	6.4	
West	14.6	19.4	52.7	8.0	5.2	
SR DM						0.0365
No	14.4	19.8	51.1	8.6	6.2	
Yes	16.7	20.0	48.7	8.4	6.2	
SR HTN						0.0001
No	13.9	19.2	52.4	8.7	5.8	
Yes	16.0	20.5	48.6	8.3	6.6	
CVD						0.0151
No	14.5	20.0	51.0	8.5	6.1	
Yes	17.1	18.9	48.4	8.7	6.9	
FH CKD						0.5107
No	14.7	19.7	50.8	8.6	6.2	
Yes	15.8	20.3	49.7	8.3	6.0	
DM mother[c]	27.3	25.1	26.8	30.1	34.6	<0.0001

CKD, chronic kidney disease; CVD, cardiovascular disease; DM, diabetes mellitus; FH, family history; HTN, hypertension; KEEP, Kidney Early Evaluation Program; SR, self-reported.
[a]Values are percents except as noted.
[b]χ^2-test for the difference in proportions of participants in each birth-weight category by different characteristics.
[c]Percent of participants with diabetic mothers in each birth-weight category.

developing to renal failure. Much evidence showed a direct relationship between birth weight and nephron number and an inverse relationship between birth weight and glomerular size.[3–6] A correlation between nephron number, low birth weight, and hypertension was also reported.[3,4]

High birth weight may imply macrosomia and diabetes or insulin resistance in the mother, and hence genetic predisposition for future CKD. The association of high birth weight and a history of maternal diabetes was also observed in our study.

Our database was large enough to demonstrate two important ideas: (1) low birth weight, probably mediated through low nephron mass, is associated with CKD in later adulthood; and (2) high birth weight, probably due to its association with maternal and future insulin resistance and hypertension, is also associated with future CKD.

Our finding that the association of birth weight and CKD depends on gender is new and unexpected. The U-shaped relationship of birth weight and CKD was significant at both ends for men but not for women in the KEEP population. This contrasts with some findings of a study conducted in the southeastern United States.[11] In studying the association of birth weight and end-stage renal disease, Lackland *et al.*[11] found that low birth weight, less than 2500 g, is significantly

Table 2 | Prevalence of kidney-related outcomes across birth-weight categories by gender and race (%)[a]

Population[b]	Kidney-related outcomes	Birth weight (g)					P^c
		<2500	2500–2999	3000–3999	4000–4499	⩾4500	
Male							
All (*n*=2920)	ACR ⩾30 mg/g	15.8	11.3	9.4	8.3	11.8	0.0069
	eGFR <60 ml per min per 1.73 m^2	18.8	14.6	13.2	18.1	19.9	0.0033
	CKD[d]	30.3	22.7	20.2	24.2	28.0	0.0003
White (*n*=1761)	ACR ⩾30 mg/g	17.0	11.1	7.8	7.3	9.1	0.0020
	eGFR <60 ml per min per 1.73 m^2	24.2	18.9	15.2	18.4	21.7	0.0210
	CKD[d]	34.6	25.5	20.5	24.0	25.9	0.0012
African American (*n*=741)	ACR ⩾30 mg/g	15.7	13.8	11.7	7.7	16.7	0.3648
	eGFR <60 ml per min per 1.73 m^2	13.1	8.9	8.3	13.5	14.9	0.2307
	CKD[d]	26.2	19.5	18.0	18.8	29.9	0.0925
Female							
All (*n*=9444)	ACR ⩾30 mg/g	10.3	9.6	9.1	8.0	8.9	0.4717
	eGFR <60 ml per min per 1.73 m^2	18.7	17.1	17.5	19.8	17.7	0.4397
	CKD[d]	26.3	24.4	24.2	25.7	24.6	0.4973
White (*n*=5343)	ACR ⩾30 mg/g	8.6	7.7	8.2	7.5	7.9	0.9533
	eGFR <60 ml per min per 1.73 m^2	23.3	21.7	21.1	24.5	19.4	0.3584
	CKD[d]	29.4	27.3	26.8	29.3	26.1	0.5489
African American (*n*=2802)	ACR ⩾30 mg/g	11.3	12.1	10.1	7.0	11.4	0.3513
	eGFR <60 ml per min per 1.73 m^2	12.6	11.8	11.5	10.1	16.1	0.5245
	CKD[d]	21.7	21.4	19.3	16.4	24.8	0.2616

ACR, albumin/creatinine ratio; CKD, chronic kidney disease; eGFR, estimated glomerular filtration rate.
[a]Denominators are number of people in each category of birth weight within each gender and race.
[b]Other races are not shown in the table.
[c]χ^2-test for the difference in prevalence of each kidney-related outcome in each category of birth weight within each gender and race.
[d]eGFR <60 ml per min per 1.73 m^2 or ACR ⩾30 mg/g.

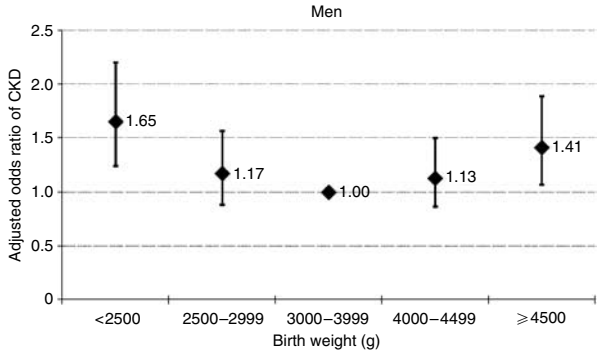

Figure 2 | Odds ratios of CKD for men by birth weight: results from multivariable logistic regression, adjusted for age; race; education; insurance status; region; self-reported diabetes, hypertension, or cardiovascular disease; family history of kidney disease; and hypertension control.

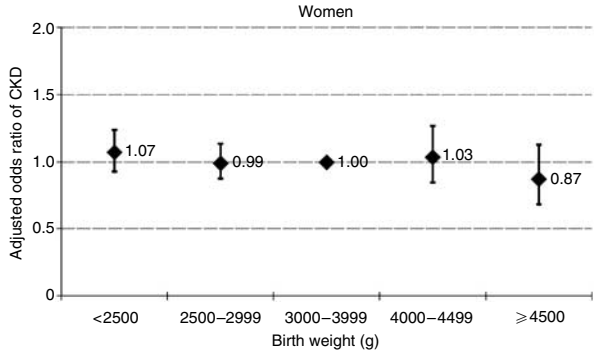

Figure 3 | Odds ratios of CKD for women by birth weight: results from multivariate logistic regression, adjusted for age; race; education; insurance status; region; self-reported diabetes, hypertension, or cardiovascular disease; family history of kidney disease; and hypertension control.

associated with higher risk of end-stage renal disease compared with normal birth weight (3000–3499 g) for women, but insignificant for men.[11] However, when stratifying the analysis on gender, the association of birth weight with renal failure is similar in that study. Differences between the two studies cannot be explained by sample size, because our study included 2902 men and 9444 women, and the study by Lackland *et al.*[11] included 2676 men and 1014 women. An unlikely cause of bias would be that men were more likely to remember their birth weight and thus report it

more accurately. However, there is a difference in measuring outcomes; our study outcome measures include early stages of CKD and the study by Lackland *et al.* measured end-stage renal disease. It is not clear whether there is a difference in glomerular number and size by gender. One study found a significantly lower nephron number for women than for men among 140 adults aged 18–65 years, with no significant difference in birth weight.[4]

One hypothesis to explain the gender differences in the association of birth weight and CKD might be that estrogen could counterbalance the impact of birth weight on the progression of CKD, by decreasing the proliferative and prosclerotic properties of mesangial cells and decreasing collagen synthesis. Perhaps the impact of hypertension, which typically occurs earlier in men, an early exposure to insulin resistance, or angiotensin-mediated profibrotic effects of testosterone made men more susceptible to the effects of a reduced nephron number.[15–18] However, our study might be biased due to uncontrolled variations. For example, we did not have data on gestational age and prematurity. In addition, due to the gender disparity in the number of participants in this study, unobserved differences may influence the associations between gender.

In our study, the association between birth weight and CKD was not significantly different between white subjects and African Americans, although CKD prevalence was higher among white subjects than among African Americans. However, previous studies showed racial differences in the association of birth weight with nephron number and the association of nephron number with mean arterial pressure.[3,4] Among 106 subjects aged 30–65 years, the correlation between birth weight and nephron number was stronger among white subjects than African Americans ($r = 0.555$, $P = 0.003$ for white subjects; $r = 0.437$, $P = 0.002$ for African Americans); the correlation between nephron number and mean arterial pressure was significant for white subjects but not for African Americans ($r = -0.455$, $P = 0.005$ for whites; $r = -0.137$, $P = 0.382$ for African Americans).[3,4]

Two strengths of our study are the sample size, which is large enough to stratify analyses on gender, and diverse populations including white, African American, and other race/ethnicity. Our study has all the limitations of a cross-sectional study. The association between birth weight and CKD prevalence cannot be viewed as causative. Further, the National Kidney Foundation KEEP participants represent a volunteer population with a high risk of CKD, and the results from this study do not generalize to the population as a whole. In addition, about two-thirds of eligible KEEP participants did not recall their birth weights, possibly also limiting the generalizability of study results. Finally, self-reported birth weight may also limit generalizability of the study results. Age is a significant determinant of the accuracy of self-reported birth weight.[19,20] Correlations between actual and self-reported birth weight were 0.64 for elderly people,[19] 0.86 for those aged 43–78 years, and 0.94 for those aged 43–50 years.[20] The associations of self-reported birth weight and prevalence of different diseases have been reported previously.[21–23]

We believe that our study provides important new information about the association of birth weight and CKD, particularly for those at greatest risk of CKD. Studies on the association of birth weight and CKD, and whether factors such as socioeconomic status and hypertension control could attenuate this association, may be needed. Effort must be made to understand clinically the etiology of the association of birth weight and CKD, and to identify attenuating factors, in the interests of improving public health.

MATERIALS AND METHODS

Subjects

In 1997, the initial KEEP program was piloted in 21 cities and screened almost 900 individuals.[24] In August 2000, KEEP was officially launched nationwide. KEEP recruitment methods and screening protocols have been described previously.[24,25] All eligible participants are required to give informed consent before they are allowed to participate in the KEEP health screening program. Each participant is asked to complete a health questionnaire; allow measurements of weight, height, blood pressure, and blood sugar; and submit blood and urine samples for additional off-site biochemical testing. The current study included KEEP participants screened from August 2000 through December 2005, from 48 National Kidney Foundation affiliates and 1245 screening programs in 48 states.

Inclusion criteria

Eligible KEEP participants are aged 18 years or older and have diabetes or hypertension or a first-degree relative with kidney disease, diabetes, or hypertension. Of the 55 220 eligible KEEP participants, 32% (17 546) reported their birth weights on the KEEP questionnaires. Older participants and members of minority groups were less likely to report birth weights.

Among the 17 546 participants who reported their birth weights, 820 aged older than 75 years were excluded, as were 3216 with missing data for any outcome variable (serum creatinine, ACR, and GFR) and 1146 with missing data for any independent variable (age, race, education level, region of residence, any self-reported disease, and family history of kidney disease). The final sample size was thus 12 364 participants aged 18–75 years.

To check the reliability of recall for birth weight, we examined consistency in reporting birth weight at different times. Of the 2717 individuals who came to a second screening, 16.4% (445 of 2717) recalled their birth weights at the first and the second screening. Of these 445 individuals, 95.5% (425 of 445) recalled the same weight or a different weight within 1 lb.

Measures

Serum creatinine was measured on the Olympus 400-640 alkaline picrate assay at Satellite Laboratories from 1 August 2000 to 31 October 2005, and on the Abbott ARCHITECT c8000 using a kinetic alkaline picrate assay at Central Laboratory Services from 1 November 2005 to the present. Both assays were calibrated to the Roche P-Module creatinine enzymatic assay at the Cleveland Clinic Research Laboratory, which has been shown to be equivalent to creatinine reference values.[26] For Satellite Laboratories, creatinine values were subtracted by 0.04 to obtain standardized values and for

the Central Laboratory Services, creatinine values were multiplied by 1.07 and then subtracted by 0.18.

Measures for kidney-related outcomes included prevalence of ACR 30 mg/g or greater, estimated GFR less than 60 ml per min per 1.73 m^2, and CKD. CKD was defined by estimated GFR less than 60 ml per min per 1.73 m^2 or ACR 30 mg/g or greater. GFR was estimated using the re-expressed Modification of Diet in Renal Disease Study Equation $(175 \times (\text{calibrated serum creatinine})^{-1.154} \times \text{age}^{-0.203})$ and adjusted by multiplying by 0.742 for women and 1.21 for African Americans.[27]

Birth weight was recorded in pounds in the questionnaire and converted to grams for analysis. We categorized the study population by five birth-weight groups: less than 2500 g, 2500–2999, 3000–3999, 4000–4499, and $\geqslant$4500 g . Other covariates used in the analysis were age; gender; race; insurance coverage (yes or no); more than high school education (yes or no); region (northeast, midwest, south, or west); self-reported diabetes, hypertension, or cardiovascular disease; family history of kidney disease; and hypertension control (systolic blood pressure less than 140 mm Hg and diastolic blood pressure less than 90 mm Hg).

Statistical methods

Univariate analyses were used to compare covariates and kidney disease outcomes across the five birth-weight categories. We performed multivariable logistic regression to examine the association of birth weight and CKD after adjustment for age; gender; race; insurance coverage; education; region; and prevalence of diabetes, hypertension, cardiovascular disease; and family history of kidney disease. Interactions between birth-weight categories and gender or race were examined. SAS version 9.1 was used for the analyses.[28]

DISCLOSURE

The KEEP is a program of the National Kidney Foundation Inc., and is supported by Amgen, Abbott, Genzyme, Ortho Biotech Products, LP, and Novartis. Additional support is provided by Siemens Medical Solutions Diagnostics, Lifescan, Suplena, and OceanSpray Cranberries. The authors have no conflicts of interest with the subject matter of this manuscript.

ACKNOWLEDGMENTS

We thank Chronic Disease Research Group colleagues Nan Booth, MSW, MPH, for manuscript editing, C Daniel Sheets and Frank Daniels for data preparation, and Shane Nygaard for manuscript preparation, and Monica R Gannon, KEEP director, for regulatory assistance.

REFERENCES

1. Brenner BM, Garcia DL, Anderson S. Glomeruli and blood pressure. Less of one, more the other? *Am J Hypertens* 1988; **1**: 335–347.
2. Brenner BM, Chertow GM. Congenital oligonephropathy and the etiology of adult hypertension and progressive renal injury. *Am J Kidney Dis* 1994; **23**: 171–175.
3. Douglas-Denton RN, McNamara BJ, Hoy WE *et al.* Does nephron number matter in the development of kidney disease? *Ethn Dis* 2006; **16**: S2–S5.
4. 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**: 671–678.
5. Manalich R, Reyes L, Herrera M *et al.* Relationship between weight at birth and the number and size of renal glomeruli in humans: a histomorphometric study. *Kidney Int* 2000; **58**: 770–773.
6. Hughson M, Farris III AB, Douglas-Denton R *et al.* Glomerular number and size in autopsy kidneys: the relationship to birth weight. *Kidney Int* 2003; **63**: 2113–2122.
7. Keijzer-Veen MG, Schrevel M, Finken MJ *et al.* Microalbuminuria and lower glomerular filtration rate at young adult age in subjects born very premature and after intrauterine growth retardation. *J Am Soc Nephrol* 2005; **16**: 2762–2768.
8. Rodriguez-Soriano J, Aguirre M, Oliveros R, Vallo A. Long-term renal follow-up of extremely low birth weight infants. *Pediatr Nephrol* 2005; **20**: 579–584.
9. Nelson RG, Morgenstern H, Bennett PH. Birth weight and renal disease in Pima Indians with type 2 diabetes mellitus. *Am J Epidemiol* 1998; **148**: 650–656.
10. Hoy WE, Rees M, Kile E *et al.* A new dimension to the Barker hypothesis: low birthweight and susceptibility to renal disease. *Kidney Int* 1999; **56**: 1072–1077.
11. Lackland DT, Bendall HE, Osmond C *et al.* Low birth weights contribute to high rates of early-onset chronic renal failure in the Southeastern United States. *Arch Intern Med* 2000; **160**: 1472–1476.
12. Fan ZJ, Lackland DT, Lipsitz SR, Nicholas JS. The association of low birthweight and chronic renal failure among Medicaid young adults with diabetes and/or hypertension. *Public Health Rep* 2006; **121**: 239–244.
13. Tulassay T, Vasarhelyi B. Birth weight and renal function. *Curr Opin Nephrol Hypertens* 2002; **11**: 347–352.
14. Wani M, Kalra V, Agarwal SK. Low birth weight and its implication in renal disease. *J Assoc Physicians India* 2004; **52**: 649–652.
15. Reyes D, Lew SQ, Kimmel PL. Gender differences in hypertension and kidney disease. *Med Clin North Am* 2005; **89**: 613–630.
16. Blush J, Lei J, Ju W *et al.* Estradiol reverses renal injury in Alb/TGF-beta1 transgenic mice. *Kidney Int* 2004; **66**: 2148–2154.
17. Negulescu O, Bognar I, Lei J *et al.* Estradiol reverses TGF-beta1-induced mesangial cell apoptosis by a casein kinase 2-dependent mechanism. *Kidney Int* 2002; **62**: 1989–1998.
18. Neugarten J, Acharya A, Silbiger SR. Effect of gender on the progression of nondiabetic renal disease: a meta-analysis. *J Am Soc Nephrol* 2000; **11**: 319–329.
19. Kemp M, Gunnell D, Maynard M *et al.* How accurate is self reported birth weight among the elderly? *J Epidemiol Community Health* 2000; **54**: 639.
20. Allen DS, Ellison GT, dos I SS *et al.* Determinants of the availability and accuracy of self-reported birth weight in middle-aged and elderly women. *Am J Epidemiol* 2002; **155**: 379–384.
21. Troy LM, Michels KB, Hunter DJ *et al.* Self-reported birthweight and history of having been breastfed among younger women: an assessment of validity. *Int J Epidemiol* 1996; **25**: 122–127.
22. Sanderson M, Williams MA, White E *et al.* Validity and reliability of subject and mother reporting of perinatal factors. *Am J Epidemiol* 1998; **147**: 136–140.
23. Bergstrom A, Lindblad P, Wolk A. Birth weight and risk of renal cell cancer. *Kidney Int* 2001; **59**: 1110–1113.
24. Brown WW, Collins A, Chen SC *et al.* Identification of persons at high risk for kidney disease via targeted screening: the NKF Kidney Early Evaluation Program. *Kidney Int Suppl* 2003; **83**: S50–S55.
25. Brown WW, Peters RM, Ohmit SE *et al.* Early detection of kidney disease in community settings: the Kidney Early Evaluation Program (KEEP). *Am J Kidney Dis* 2003; **42**: 22–35.
26. Levey AS, Coresh J, Greene T *et al.* Expressing the Modification of Diet in Renal Disease Study equation for estimating glomerular filtration rate with standardized serum creatinine values. *Clin Chem* 2007; **53**: 766–772.
27. Levey AS, Coresh J, Greene T *et al.* Using standardized serum creatinine values in the modification of diet in renal disease study equation for estimating glomerular filtration rate. *Ann Intern Med* 2006; **145**: 247–254.
28. SAS Inst Inc. (Version 9.1) 2003; Cary: NC, USA.