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Academic achievement in children with chronic kidney disease: a report from the CKiD cohort

Lyndsay A. Harshman[1], **Rebecca J. Johnson**[2], **Matthew B. Matheson**[3], **Amy J. Kogon**[4,8], **Shlomo Shinnar**[5], **Arlene C. Gerson**[6], **Bradley A. Warady**[7], **Susan L. Furth**[4,8], and **Stephen R. Hooper**[9]

[1]Division of Pediatric Nephrology, University of Iowa Stead Family Department of Pediatrics,

[2]Children's Mercy Kansas City, Division of Developmental and Behavioral Sciences,

[3]Johns Hopkins Bloomberg School of Public Health,

[4]Division of Nephrology, Children's Hospital of Philadelphia,

[5]Departments of Neurology, Pediatrics and Epidemiology and Population Health, Montefiore Medical Center, Albert Einstein College of Medicine,

[6]Johns Hopkins University School of Medicine,

[7]Children's Mercy Kansas City, Division of Pediatric Nephrology,

[8]Department of Pediatrics, Perelman School of Medicine at the University of Pennsylvania,

[9]Department of Allied Health Sciences, University of North Carolina School of Medicine

Abstract

Background and objectives: There are limited data to describe academic achievement outcomes for children with mild to moderate pediatric chronic kidney disease (CKD). The objective of this study was to describe the prevalence of low academic achievement in patients with mild to moderate CKD.

Design, Setting, Participants, and Measurements: Wechsler Individual Achievement Test, Second Edition, Abbreviated (WIAT-II-A) data were collected at entry into the Chronic Kidney Disease in Children (CKiD) study. Achievement in basic reading, spelling, mathematics, and total achievement was evaluated with a focus on the effects of comorbid CKD-related variables, neurocognitive, and school-based characteristics on academic achievement.

Results: WIAT-II-A data were available for 319 children in the CKiD cohort. Low total academic achievement was present in 34% percent of the sample. There was no significant effect of CKD-related medical variables on academic achievement. Mathematics had the lowest distribution of achievement scores. In univariate models, low achievement was significantly related to days of missed school ($p = 0.006$) and presence of individualized education plan ($p < 0.0001$).

Address correspondence to: Lyndsay Harshman, MD, Stead Family Department of Pediatrics, Division of Pediatric Nephrology, 4037 Boyd Tower, 200 Hawkins Drive, Iowa City, Iowa 52242, p. 319-356-7249/f. 319-384-9616, lyndsay-harshman@uiowa.edu.

The CKiD protocol received approval by the Institutional Review Boards at each center.

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Conclusions: Low academic achievement was seen in over one-third of children with CKD, with the most difficulty observed in the domain of mathematics. Providers and educators should monitor for academic difficulties in this population in order to facilitate early educational assistance and promote positive educational outcomes.

Keywords

academic achievement; pediatric; chronic kidney disease

Introduction

The physical sequelae of pediatric chronic kidney disease (CKD) are well characterized [1]. Data support the parallel presence of subtle neurocognitive deficits in even mild to moderate pediatric CKD. Specifically, cognitive executive function, the neurocognitive ability to plan and make complex decisions, may be impaired in CKD [2]. As with executive function, behavioral concerns are reported by parents of children with CKD [3]. Although the specific mechanisms of neurocognitive and behavioral dysfunction associated with CKD are not fully understood, there is evidence to suggest that decline in renal function, early age of onset, and proteinuria increase the risk for neurocognitive and behavioral shortfalls even before the disease advances to the need for dialysis or transplantation [4].

Despite growing awareness of neurocognitive weaknesses within this population, there are limited data on the spectrum of academic achievement in mild to moderate pediatric CKD. Single-center data suggest a trend for overall lower single-test achievement scores in mathematics and reading with worsening renal function predicting lower total achievement composite scores [5]. An initial evaluation of academic achievement data collected as part of the Chronic Kidney Disease in Children (CKiD) multi-center prospective cohort study [4] suggested that general academic achievement scores were largely skewed toward the lower end of the normal range in CKD and that lower renal function may be associated with lower achievement.

For the present study, secondary data analysis was performed and utilized study data from children enrolled in the CKiD prospective cohort study in order to: (1) define the range of academic achievement in mild to moderate pediatric CKD and (2) examine the effects of individual, CKD-related, neurocognitive-behavioral, and school-based characteristics on academic achievement within the population.

Methods

The study sample included participants enrolled in the CKiD prospective cohort study. The CKiD study is a multi-center study conducted at 57 pediatric nephrology centers in North America and funded by the National Institutes of Health to examine various aspects of mild to moderate CKD progression estimated glomerular filtration rate [(eGFR) 30–90 ml/min/ $1.73m^2$ for participants at time of study enrollment], including the impact of disease on neurocognition [4, 6]. Details of the study design, inclusion and exclusion criteria, and methods have been published previously [6]. Of note, children with intellectual disabilities and those with genetic syndromes with central nervous system manifestations were excluded

by study design. The CKiD protocol received approval by the Institutional Review Boards at each center.

The CKiD study included assessment of individual academic achievement using the Wechsler Individual Achievement Test, Second Edition, Abbreviated (WIAT-II-A) at the baseline neurocognitive assessment (see Furth, 2006 [6]). This analysis includes all participants enrolled in CKiD ages 6 and older with WIAT-II-A test data available. Achievement in basic reading, spelling, mathematics, and total achievement were evaluated with a focus on the effects of individual, CKD-related (i.e., estimated renal function, proteinuria, hypertension, anemia, and metabolic disease), neurocognitive-behavioral, and school-based characteristics on academic achievement within the population. In anticipation of potential confounders, such as fatigue secondary to order effects, the full neurocognitive battery (of which the WIAT-II-A was a part) was administered as two separate blocks, and the blocks were counterbalanced across participants. The psychologist/psychometricians performing the assessments rated the validity of the administration.

Assessment of Chronic Kidney Disease

CKiD participants have well-characterized renal function [7] in addition to routine laboratory assessment for anemia, proteinuria and bone-metabolic disease. Anemia is also quantified for participants based on need for use of erythropoietin-stimulating agent or hemoglobin below National Kidney Foundation Kidney Disease Outcomes Quality Initiative (NKF K-DOQI) thresholds for age and sex [8]. In-office blood pressure assessment is precisely measured through standardized approach at each visit to monitor for interval development or worsening of hypertension requiring therapy [9].

Assessment of Academic Achievement

The complete CKiD neurocognitive battery has been previously described in detail [4, 6] and included the WIAT-II-A as a validated measure of academic achievement at visit 1b. Of note, the WIAT-II-A was administered until year three of the CKiD study and discontinued at that time; as such, data was analyzed for only those participants who were enrolled and had neurocognitive evaluation completed within the first three years of the CKiD study.

The WIAT-II-A provides an estimate of the child's composite academic performance (Total Achievement score) in addition to individual content domain scores in reading, math, and spelling. The WIAT-II-A has a standard score of 100 and a standard deviation of 15. Scores of 90 or lower represent the bottom quartile and are suggestive of low achievement. All participants completed the Wechsler Abbreviated Scale of Intelligence (WASI) to assess intelligence (IQ) at time of initial neurocognitive evaluation. Children with an IQ score of less than 80 were excluded from analysis.

Statistical analysis

Analysis was performed utilizing data for children enrolled in the CKiD study who had completed WIAT-II-A assessment. We first defined the range of academic achievement in mild to moderate pediatric CKD. In line with limited, existing literature, we predicted a distribution of average to low-average scores for overall academic achievement and that

mathematics would yield the lowest subtest scores. To assess the prevalence of low academic achievement, we quantified low achievement as a score in the bottom quartile (i.e., age-based standard score ≤ 90) on the Total achievement composite score. Low achievement in focal content areas was identified by a score in the bottom quartile (as above, age-based standard score ≤ 90) on any one or more of three WIAT-II-A subtests.

A logistic regression model was used to estimate effects on odds of low achievement based on 1) individual, 2) CKD-related, and 3) neurocognitive-behavioral characteristics on academic achievement within the population. Based on existing data, we hypothesized lower renal function (as measured by eGFR using the 2012 CKiD equation [7]) and duration of disease would predict low achievement. We hypothesized that neurocognitive measures of executive functioning, attention, and parent-reported measures of child behavior, would be associated with low achievement.

The final model included individual-level covariates of age, sex, African-American race, Hispanic ethnicity, maternal education (high school or less, some college, college or more), and household income. CKD-related covariates included eGFR, percent of life with CKD, nephrotic proteinuria (urine protein:creatinine ratio > 2), hypertension (defined as casual systolic or diastolic blood pressure ≥ 95th percentile for age, sex and height; or self-reported diagnosis of hypertension plus antihypertensive medication use), anemia (defined as hemoglobin below KDOQI thresholds for age and sex or use of an erythropoiesis-stimulating agent), low birth weight (<2500 grams), presence of seizures, and parent-reported ADD/ADHD. Disease type (e.g., glomerular versus non-glomerular etiologies) was not included in the final model given that the preliminary model showed no significant interaction between disease type and achievement outcomes. Neurocognitive-behavioral variables in the model included the Global Executive Composite (GEC) score from the parent-completed Behavior Rating Inventory of Executive Function (BRIEF) and three composite scores from the Behavior Assessment System for Children, Second Edition-Parent Rating Scales (BASC-2 PRS): Internalizing Problems, Externalizing Problems, and Adaptive Skills.

We also compared the low achieving group directly to the remainder of the assessed CKiD group (those with average to above-average achievement) on school-related measures including individualized education plan (IEP) or 504 plan usage, and parent-reported school absences with use of univariate analysis. A 504 plan is a formalized plan for how a child with a physical or mental disability will have accommodations to ensure academic success and access to the learning environment. This formalized plan provides services and changes to the learning environment to meet the needs of the child as adequately as other students. It should be noted, though, that this is not an IEP as dictated by special education law but, rather, dictated by the disabilities act.

Fisher’s exact test or Wilcoxon rank-sum test was used for each comparison as appropriate. SAS 9.2 (SAS Institute, Cary, NC, USA) and S-Plus 8.2 (TIBCO Software, Palo Alto, CA, USA) were used for analysis and figure generation.

Results

Sample description

WIAT-II-A data were available for 319 children in the CKiD cohort. Table 1 provides a description of the socio-demographic and CKD-related variables for this sample. With a median age of 12.7 years, the group was 64% male, 17% African American, and 13% with Hispanic ethnicity. The median parent-reported duration of diagnosed CKD was 10.2 years. Median eGFR for the group was 43.3 ml/min per 1.73 m^2 (interquartile range (IQR), 33.7–55.0 ml/min per 1.73 m^2), representative of CKD stage 2–3. Etiology of disease was glomerular in nature for 25% of the group. Hypertension (defined as casual systolic or diastolic blood pressure ≥ 95th percentile for age, sex and height; or self-reported diagnosis of hypertension plus antihypertensive medication use) and anemia (defined as hemoglobin below K-DOQI thresholds for age and sex or use of an erythropoiesis-stimulating agent) were present for 51% and 45% of the sample, respectively.

Prevalence of low achievement

Figure 1 shows the overall and individual content domain achievement outcomes for the sample. Thirty-four percent of the sample had Total achievement scores that represented low achievement (age-based standard score ≤ 90). Low achievement was most pervasive in the content domain Numerical Operations (mathematics), with 33% percent of the sample scoring in the bottom quartile (Figure 1). Twenty-two percent of the sample had scores in the bottom quartile for only one subtest, with 13% of the sample under-performing on two subtests, and another 13% showing evidence of low achievement on all three subtests (Table 2).

CKD-related factors associated with achievement

CKD-related characteristics including eGFR, proteinuria, hypertension, and anemia were not associated with low achievement.

Individual-level risk for low achievement

In univariate comparisons, low achievement was significantly associated with lower levels of maternal education ($p = 0.0002$), African-American race ($p = 0.007$), and lower socioeconomic status, as defined by household income less than $36,000/year ($p = 0.0004$). In models adjusted for CKD-related, neurocognitive, and behavioral factors, maternal education of college or more versus high school or less provided an attenuated risk for low achievement in all content areas ($p<0.02$). Boys and girls had generally equivalent Total achievement scores; however, boys did demonstrate an OR = 0.505 (95% CI 0.267–0.956, p=0.04) for low achievement on Numeric Operations, indicating better achievement among boys.

Neurocognitive-behavioral assessment

As reported previously for the entire CKiD cohort [4], median Full Scale IQ was 100 with IQR of 91–109. In terms of behavioral predictors, the only detected signal was a diminished risk of low achievement on Word Reading for subjects with higher Adaptive Skills

(OR=0.580, 95% CI 0.371–0.906). Executive function, as measured via the Global Executive Composite (GEC), score from the Behavior Rating Inventory of Executive Function was not associated with low academic achievement. Model-based odds ratio estimates and confidence intervals for neurocognitive and behavioral predictors are shown in Figure 2. The presence of ADD/ADHD was self-reported for 9% of the sample; however, this was not significantly associated with risk for academic underachievement.

School-based characteristics

School-specific factors were assessed in relation to low achievement. All participants attended school and the median grade level at study entry was 5.5 (IQR 2.0–8.0). The median number of parent-reported days absent from school within the past year for medical reasons was 4 (IQR 2–10 days). In unadjusted comparisons, children displaying lower Total achievement scores had more school absences (5.5 days versus 3 days, $p < 0.006$). Use of an IEP or 504 plan was reported by 29% of the sample. Children with lower Total achievement scores also had a higher rate of IEP or 504 plan usage (51% versus 17%, $p < 0.0001$).

Discussion

The purpose of this study was to address critical gaps in our knowledge of academic achievement outcomes for children with mild to moderate CKD. This study utilized a large, representative sample to evaluate composite and content-specific academic achievement with the aim of defining the prevalence of low achievement in the CKiD sample. The study also examined how academic achievement is related to discrete, disease-related markers of CKD in parallel with neurocognitive-behavioral factors that are known to be associated with progression of pediatric CKD and participant use of school-based services.

Results from this study provide robust descriptive data on the prevalence of low achievement outcomes in children with mild to moderate CKD. As a whole, data support the potential for lower academic achievement outcomes in this population with mathematics producing the lowest content-specific distribution of scores. It is important to emphasize that although 34% of the sample demonstrated low achievement, the median total achievement score for the sample was within the average range of functioning.

Previous studies have suggested a more pervasive low-achievement status in pediatric CKD patients; however, these studies have included mixed samples with greater disease severity (e.g., dialysis-dependent) not included in this sample [5, 10, 11]. Given the generally mild disease spectrum captured within our sample, it is certainly possible that the late and long-term effects of CKD on academic achievement have not yet materialized in our sample at the baseline visit. Perhaps not surprisingly given the mild degree of disease present – along with assessment of academic achievement early in the CKiD study – medical variables related to CKD progression showed no discriminatory ability to predict low achievement within the sample. In contrast to previous studies [4, 5, 12], there was no association between renal function and academic achievement. Low achievement was not associated with presence of hypertension, anemia, or proteinuria at the point in the disease process when patients were assessed for the CKiD study.

Interestingly, presence of ADHD was reported in 9% of the sample – slightly higher than the 7.2% prevalence reported worldwide for the general pediatric population [13]. We did not anticipate a higher rate of ADHD in the pediatric CKD population; however, this may not necessarily be surprising. The comorbidity of ADHD with learning problems can be quite high and may provide some explanation as to why our sample seems to have a slightly higher rate of ADHD. Substantial data exist to document the co-occurrence of attention disorders and low achievement, particularly in the domain of mathematics, within the general population [14, 15]. For example, difficulty sustaining attention may interfere with the ability to master abstract symbol systems and interfere with mathematical operations, especially in basic arithmetic skills in the primary grades. This effect is thought to be augmented in the CKD population whereby children with even mild to moderate CKD are more likely to experience deficits in attention regulation on neurocognitive assessment [2]. Although there was no significant association between assessments of executive functioning (GEC) or ADHD with academic achievement outcomes, it may be plausible that subtle attentional deficits, not well measured at the time of this assessment, but often noted with progression of pediatric CKD, may be a key factor for underlying academic difficulty in mathematics for this population, not simply an independent feature thereof.

Early childhood academic achievement is a predictor of occupational goals and later career success [16]. This is particularly salient considering previous single-center data indicating a higher rate of supplementary school service usage [17–19], more frequent school absenteeism and grade retention [5], and lower high school graduation rates [20] for children and adolescents with CKD. Thus, surveillance for low achievement should not be considered an afterthought in this population, particularly given that nearly 30% of this sample with mild to moderate CKD received some form of supplemental school support. Further, and as might be expected, those with an IEP and frequent absences from school were actually more likely to evidence low achievement (Table 3). This latter finding was not surprising and may impact most significantly on academic domains such as mathematics where content tends to be hierarchical with math procedures and processes changing with advancing grades. These findings mirror established education trends, namely that maternal education and socioeconomic status predict lower academic achievement on core academic skills.

This study is the most in-depth review of academic achievement outcomes for children with mild to moderate CKD published to date. Data presented here yield valuable insight into the prevalence of low academic achievement in pediatric CKD, indicating presence of low achievement in over 30% of children with CKD; however, it is important to note that approximately two-thirds of this mildly affected CKD sample, at baseline, seemed to have achieved age-appropriate, core academic skills for their chronological age and grade placement. This study has several strengths including the large size, a well-characterized patient population, use of a standardized measure of academic achievement, and detailed attention to CKD-related, neurocognitive, social-behavioral, and socio-demographic factors.

Despite these strengths, there are limitations that should be mentioned. Specifically, academic achievement data were not measured longitudinally in the CKiD study; thus, data were examined at a single time point at study enrollment. Furthermore, the WIAT-II-A was only administered for the first three years of the CKiD study, which limits the number of

observations and thus the statistical power of our analyses. Thus, we are unable to determine the effect that decline in renal function for individual participants may have on longitudinal academic achievement; hence, the long-term contribution of renal (disease) variables to achievement may not fully be captured.

Certainly, many more covariates have potential associations with achievement outcomes, but further adjustment risks over-fitting the model. As such, we chose a targeted set of covariates to balance novel research interests with known risk factors for neurocognitive deficits. We did adjust for maternal education and parental income in our model to account for possible influence of socioeconomic status on academic achievement. Review of data from the 2015 United States Census shows that our sample has similar maternal education to the general population, with 33% of mothers in the general population having a bachelor's degree or higher compared to 35% of mothers in the CKiD population [21]. The findings of academic underachievement in this population should be considered preliminary and warrant further evaluation. Future studies should seek to replicate these findings with longitudinal follow-up and consideration of inclusion of a matched, healthy comparison group. Furthermore, although this is a standardized measure of academic achievement, it is not a "real-time" measure of actual classroom performance and may potentially under (or over) estimate a participant's actual classroom abilities.

Although the majority of the sample performed at expected levels, approximately one-third of the sample did demonstrate performance representative of lower academic achievement. As such, ongoing academic surveillance within this population is warranted given the known chronicity of this disease and the potential for parallel neurocognitive weaknesses in advanced stage CKD/ESRD (end stage renal disease). Significant opportunity exists to improve clinic- and classroom-based screening for poor academic performance in the CKD population with potential for earlier use of educational intervention services for those at risk. Close individual surveillance remains necessary despite these encouraging findings, to ensure stability in academic performance and for optimal school retention and future career success, and to modulate the impact of disease progression on academic outcomes.

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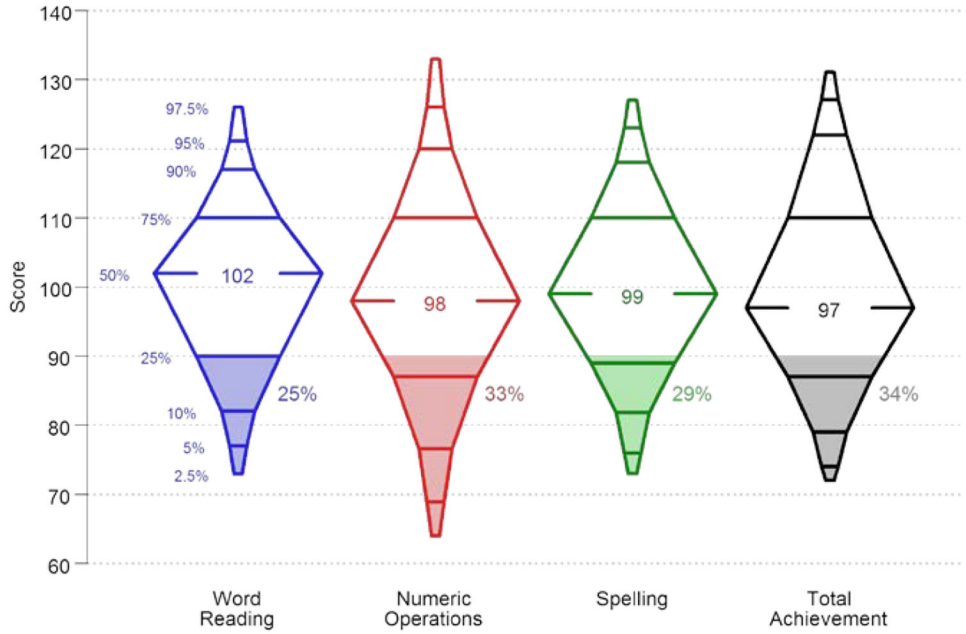

Figure 1-
Distributions of WIAT-II-A Scores and Percentage in Lowest Quartile of Normal

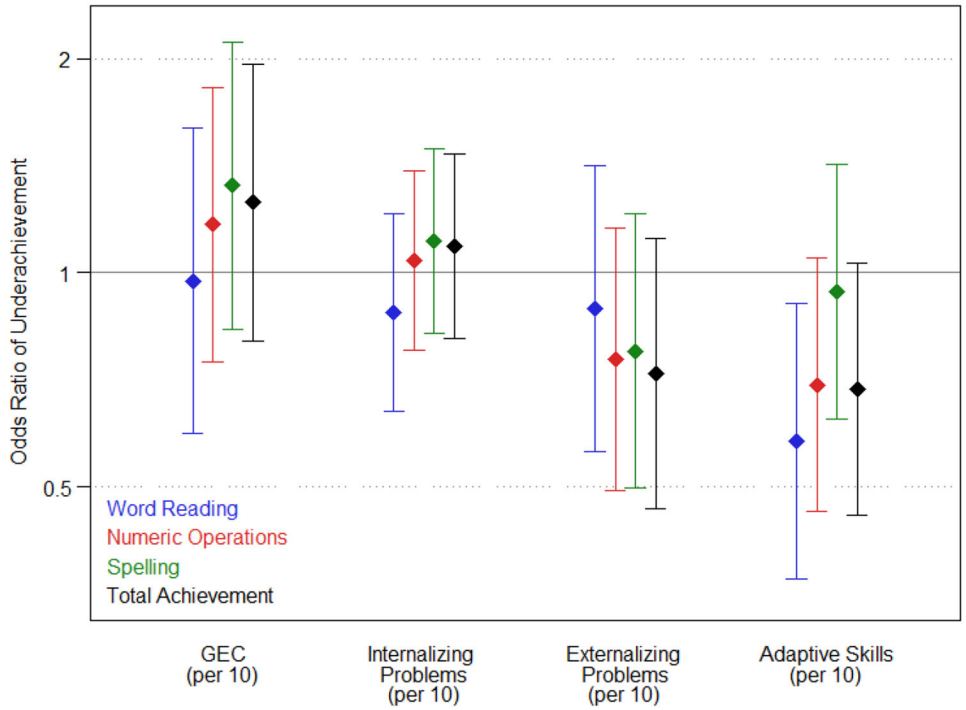

Figure 2- Odds Ratios of Academic Underachievement for Cognitive and Behavioral Predictors: This Figure displays the adjusted odds ratios of having underachievement on the WIAT subscales and Total Achievement scale based on cognitive and behavioral predictors. Odds ratios above 1 indicate greater odds of underachievement (e.g., lower Total Achievement scores).

Table 1 -

Characteristics of Sample at Study Entry

Characteristic	Median [IQR] or N (%)
Age, years	12.7 [9.6, 15.3]
Male sex	203 (64%)
African-American race	54 (17%)
Hispanic ethnicity	42 (13%)
Maternal education:	
HS or less	118 (38%)
Some college	85 (27%)
College or more	108 (35%)
Household income ≥$36,000 per year	204 (65%)
GFR	41.6 [31.8, 54.1]
Glomerular etiology	79 (25%)
Percent of life with CKD	100 [85, 100]
Duration of CKD, years	10.2 [7.3, 13.9]
Nephrotic proteinuria (uP/C > 2)	42 (14%)
Hypertension	162 (51%)
Anemia	145 (45%)
Low birth weight	45 (15%)
Seizures in past year	29 (9%)
Parent-reported diagnosis of ADHD	29 (9%)
IEP usage	68 (23%)
504 plan	30 (12%)
IEP or 504 plan	86 (29%)
Days of missed school in past year	4 [2, 10]
Full Scale IQ	100 [91, 109]

GFR glomerular filtration rate, *CKD* chronic kidney disease, *IEP* individualized education plan, *HS* High School

Table 2 -

Distribution of Low Achievement on WIAT-II-A Subscales

Scales with Low Achievement	N (%)
No deficits	167 (52%)
One subtest	69 (22%)
Word Reading	14 (4%)
Numerical Operations	37 (12%)
Spelling	18 (6%)
Two subtests	42 (13%)
Word Reading + Numerical Operations	10 (3%)
Word Reading + Spelling	16 (5%)
Numerical Operations + Spelling	16 (5%)
All three subtests	41 (13%)

Table 3 -

Comparison of Sociodemographic and School-Related Characteristics by Low Achievement

Characteristic	Total Achievement Score		p-value
	≤90 (n=108)	>90 (n=211)	
IEP usage	45 (46%)	23 (12%)	<0.0001
504 plan	17 (21%)	13 (8%)	0.004
IEP or 504 plan	52 (51%)	34 (17%)	<0.0001
Days of missed school in past year	5.5 [2, 15]	3 [2, 8]	0.006
Household income ≥$36,000/year	54 (51%)	150 (72%)	0.0004
African-American race	27 (25%)	27 (13%)	0.007
Hispanic ethnicity	16 (15%)	26 (12%)	0.49
Maternal education:			
HS or less	54 (50%)	64 (31%)	0.0002
Some college	31 (29%)	54 (26%)	
College or more	22 (21%)	86 (42%)	

IEP individualized education plan, *HS* High School