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Physical activity and screen time in adolescents in the chronic kidney disease in children (CKiD) cohort

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Abstract

Background—Self-reported physical activity (PA) and screen time exposure in adolescents with chronic kidney disease (CKD) has not been evaluated.

Methods—We performed a cross-sectional analysis of PA and screen time in 224 adolescents at entry into the Chronic Kidney Disease in Children (CKiD) cohort. We compared proportions of CKiD vs. healthy 2012 National Health and Nutrition Examination Survey (NHANES) participants reporting the recommended 60 min of PA 7 days/week or 2 h/day of entertainment screen time (binomial probability test). Within CKiD, we assessed correlates of PA and screen time using multivariable logistic and linear regression and examined longitudinal data for 136 participants.

Results—Median age of CKiD participants was 15 years, and 60 % were male. Median estimated glomerular filtration rate (eGFR) was 41.3 (IQR 30.8, 52.3) ml/min/1.73 m². Only 13 % of CKiD participants met recommendations for PA vs. 25 % of NHANES ($p < 0.001$), while 98 % in CKiD exceeded the recommended screen time vs. 73 % in NHANES ($p < 0.001$). Within CKiD, obesity ($p = 0.04$) and lower eGFR ($p = 0.02$) were independently associated with greater screen time.

Conclusions—Adolescents with CKD engage in significantly less PA and greater screen time than healthy youth in the United States, and this may worsen over time.

Keywords

Chronic kidney disease; Pediatric; Physical activity; Cardiovascular risk factors; Cardiovascular disease

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Compliance with ethical standards The Children's Hospital of Philadelphia Institutional Review Board determined that this study met eligibility criteria for exemption according to 45 CFR 102(f).

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Introduction

Children and adolescents with chronic kidney disease (CKD) are a vulnerable population at risk for progression to end-stage kidney disease (ESKD), which is associated with remarkably high rates of hospitalization and mortality [1]. For children 0–14 years of age who require dialysis, the remaining life expectancy is only 20 years [2]. Cardiovascular disease (CVD) is a significant concern in this population, both for the higher rates of cardiovascular mortality as compared to healthy peers as well as the increased risk of premature death in early adulthood due to CVD [1–11]. Overall mortality for children who progress to ESKD is 30 to 150 times higher than that of the general population and cardiovascular mortality is 1000 times higher [3, 7–10]. CVD is the leading cause of mortality in adult ESKD patients with a fourfold risk of death as compared to populations without ESKD [1, 11]. Given this burden of disease, pediatric nephrologists seek intervention points to decrease CVD risk in children and adolescents with CKD.

Adults with CKD spend almost two-thirds of their day sedentary and engaging in even light physical activity may confer an overall survival benefit [12]. It has been well documented that physical inactivity in adult CKD populations is a strong predictor of cardiovascular mortality and leads to overall poor physical functioning and decreased exercise capacity [13–15]. Physical activity may be a modifiable risk factor for CVD in this population, and new research suggests exercise should be prescribed as part of the CKD treatment regimen [16–23]. The 2012 Kidney Disease Improving Global Outcomes (KDIGO) Clinical Practice Guideline for the Evaluation and Management of Chronic Kidney Disease recommends at least 30 min of physical activity five times per week for adults with CKD; however, several studies suggest a need for clearer guidelines and better dissemination to physicians [24–27].

The 2008 U.S. Department of Health and Human Services physical activity guidelines for all American children and adolescents recommend 60 min or more of physical activity daily [28]. This recommendation was endorsed by the American Academy of Pediatrics (AAP) [29, 30]. The AAP also recommends limiting the total amount of entertainment screen time to 2 h per day for children and adolescents 2 years of age or older and recommends against any screen time for children less than 2 years of age [31, 32].

Data on physical activity in children and adolescents with pre-dialysis CKD is lacking, and there are no guidelines for physical activity in pediatric CKD. In children with ESKD, there is a U-shaped association between body mass index (BMI) and death, with both low and high BMI associated with increased mortality [33]. Children and adolescents with advanced CKD have been found to have significant deficits in lean leg mass, indicative of skeletal muscle wasting, and a recent study demonstrated decreased muscle quality in children with CKD stages 2–5D, with significantly lower muscle torque relative to muscle cross-sectional area compared to controls [34, 35]. The current body of literature regarding physical activity in children with CKD has focused on the ESKD population rather than the early stages of CKD and also suggests that physical activity may be a modifiable risk factor for later CVD mortality in adulthood [13, 36–41]. The burden of inactivity is largely unknown in the pediatric CKD population and could provide a point of intervention early in the disease course to prevent future morbidity and mortality. The objectives of this study were to

examine self-reported physical activity and screen time in adolescents with CKD in comparison with healthy peers as well as to characterize changes in physical activity and screen time with progression of CKD.

Materials and methods

Study participants

We conducted a cross-sectional analysis of adolescents aged 12–18 years with CKD participating in the Chronic Kidney Disease in Children (CKiD) study at the time of study entry ($n = 144$). We then conducted a longitudinal analysis at 1-year follow-up for a subset of these participants ($n = 136$). CKiD is a multicenter, prospective cohort study conducted at 50 sites across the United States. CKiD began enrolling participants in October 2003 (Cohort 1) and recently finished enrolling Cohort 2 [42]. Cohort 1 consists of 586 ethnically and racially diverse children with mild-to-moderate kidney dysfunction, and Cohort 2 includes 280 children with mild kidney dysfunction [42]. Eligible participants are between 1 and 16 years of age with an estimated glomerular filtration rate (eGFR) between 30 and 90 ml/min/1.73 m² [42]. The most relevant exclusion criteria for our study include: renal, other solid organ, bone marrow, or stem cell transplantation; cancer/ leukemia diagnosis or HIV diagnosis/treatment in the last 12 months; history of structural heart disease; and genetic syndromes involving the central nervous system [42]. The physical activity and screen time questionnaire was administered to participants 12 years of age and was modeled after the United States Centers for Disease Control National Health and Nutrition Examination Survey (NHANES) questionnaire. This questionnaire has been validated in children 12 years of age [43]. Comparison data for physical activity and screen time was taken from the published 2012 NHANES National Youth and Fitness Survey results [29, 31]. A total of 2065 children and adolescents ages 3–15 years took part in the survey during the 2012 calendar year [43]. Of the total participants, NHANES administered the physical activity and screen time questionnaire to 510 adolescents aged 12–15 years including 259 males and 251 females [29, 31, 43].

We obtained the publicly available CKiD data for Cohort 1, which included 259 eligible participants 12 years of age. We excluded 24 participants who did not have physical activity and screen time questionnaire data. We also excluded 11 participants who reported > 7 days of physical activity in the past 7 days. The final cross-sectional analysis included 224 participants. Of these, 136 had longitudinal data from 1 year after their baseline visit.

Physical activity and screen time outcomes

The primary study outcomes were the number of days in the past week that the participants engaged in 60 min of physical activity and the number of hours of total entertainment screen time on an average school day. Participants met physical activity recommendations if the number of days in the past week engaged in 60 min of physical activity was 7 days. Other physical activity outcome variables included: the number of days in the past week engaged in 30 min of physical activity, number of days in the past week engaged in 20 min of physical activity, number of days of physical education in the average school week, number of minutes exercising in the average physical education class, and number of sports teams

played on in the past 12 months. Participants met screen time recommendations if the total number of hours of entertainment screen time (total screen time) on an average school day was 2 h. Total screen time was calculated by adding the number of hours of TV watched and the number of hours of video games/computer use on an average school day. All outcomes were by self-report.

Covariates

The following potential correlates of physical activity and screen time were assessed: age, gender, race, height percentile, obesity, household income, primary diagnosis, and eGFR. Race was defined as white, black, or other. Participants were also asked to identify if they were of Hispanic ethnicity. Height percentile was defined by age and gender. Obesity was defined as a BMI above the 95th percentile for age and gender. Low household income was defined as less than the 2013 poverty threshold for a family of four of \$23,834. Primary diagnosis was categorized as glomerular or non-glomerular. The most prevalent diagnoses in the glomerular category were focal segmental glomerulosclerosis, hemolytic uremic syndrome, lupus, Alport's, and IgA nephropathy. The most prevalent diagnoses in the non-glomerular category were reflux nephropathy, obstructive uropathy, and dysplasia. eGFR was calculated using the updated Schwartz formula $[(0.413 \times \text{height}) / \text{serum creatinine}]$.

Analysis

Descriptive statistics were reported as median and inter-quartile range (IQR) for continuous variables and frequencies for categorical variables. Group differences in binary variables were assessed using a binomial probability test. The associations of covariates with the binary outcome variables were assessed using multivariable logistic regression and reported as odds ratios (OR) with 95 % confidence intervals (CI). The associations of covariates with the continuous outcome variables were assessed using multivariable linear regression and reported as β coefficients with 95 % CI. The associations of covariates with the ordinal physical activity variables were assessed using ordinal logistic regression and reported as β coefficients with 95 % CI. In the longitudinal analysis, differences over time in continuous measures were assessed using the paired *t* test or the Wilcoxon signed-rank test as indicated. Differences in the binary outcomes of meeting physical activity and screen time requirements over time were assessed using Generalized Estimating Equation (GEE) analysis. A two-sided *p* value of < 0.05 was considered statistically significant. Analyses were performed using Stata 13.1 (StataCorp LP, College Station, TX).

Results

Baseline characteristics (Table 1)

A total of 224 CKiD participants were included in the cross-sectional analysis with a median age of 15 years (IQR 12, 16) and median eGFR of 41.3 ml/min/1.73 m² (IQR 30.8, 52.3). Consistent with data from the U.S. pediatric ESKD population and with the larger CKiD cohort, 60 % were male and 67 % had a non-glomerular primary diagnosis [1, 2] and 19 % were black, 15 % were Hispanic, and 24 % met the threshold for low household income. The median height percentile among participants was 25.8 (IQR 7.9, 58.4), and 17 % were obese. The median number of days in the past 7 engaged in physical activity for 60 min was

3 (IQR 0, 5). This was similar for the number of days in the past 7 engaged in physical activity for 20 or 30 min. The median number of hours spent watching TV on an average school day was 4 h (IQR 3, 5), and the median number of hours spent on the computer/playing video games was 3 h (IQR 2, 4). Participants engaged in a median total screen time on an average school day of 7 h (IQR 5, 9) which is consistent with national estimates of adolescent screen time engagement [32].

CKiD and NHANES comparison (Figs. 1 and 2)

In the CKiD cohort, 13.4 % of participants met physical activity recommendations as compared to 24.8 % of NHANES participants ($p < 0.001$). There was no significant difference between males and females meeting physical activity recommendations within either the CKiD or NHANES cohorts [29]. However, physical activity in both males and females in CKiD was significantly lower than males ($p < 0.001$) and females ($p = 0.04$) in NHANES (Fig. 1a). This significant difference in physical activity held over various levels of physical activity for both males and females including 5 days engaging in 60 min of physical activity over the past week ($p < 0.001$) and > 0 days engaging in 60 min of physical activity over the past week ($p < 0.001$) (Fig. 2).

In the CKiD cohort, 1.8 % of participants met screen time recommendations as compared with 27 % of NHANES participants ($p < 0.001$). There was no significant difference between males and females within either the CKiD or NHANES cohorts [31]. However, both males and females in CKiD were significantly different from males ($p < 0.001$) and females ($p < 0.001$) in NHANES (Fig. 1b).

Regression

In the multivariable logistic regression model within the CKiD cohort, none of the covariates assessed were associated with meeting physical activity recommendations (Table 2). Similarly, none of the covariates assessed were associated with meeting screen time recommendations (Table 2). In the ordinal logistic regression model for number of days in the past 7 engaged in 60 min of physical activity, obesity was associated with decreased physical activity (β coefficient -0.95 , $p = 0.01$), and increased height percentile was associated with increased physical activity (β coefficient 0.01 , $p = 0.03$). In the ordinal logistic regression model for number of days in the past 7 engaged in 20 min of physical activity, obesity was again associated with decreased physical activity (β coefficient -0.75 , $p = 0.04$). In the ordinal logistic regression model for number of days in the past 7 engaged in 30 min of physical activity, there was no association with any of the covariates. In the multivariable linear regression model, obesity (β coefficient 1.04 , $p = 0.04$) and lower eGFR (β coefficient -0.02 , $p = 0.03$) were independently associated with greater screen time (Table 3).

Longitudinal analysis (Table 4)

The median eGFR decreased from 40.2 to 36.8 ml/min/m² ($p < 0.001$). The proportion of participants who were obese increased from 16 % at baseline to 20 % at 1 year of follow-up ($p = 0.046$). While there was no difference between the number of days engaged in various time periods of physical activity (20, 30, and 60 min), the number of participants who met

physical activity recommendations fell from 20 (14.7 %) at baseline to 10 (7.5 %) at 1 year ($p = 0.03$). Fewer participants reported playing on a sports team at follow-up ($p = 0.02$). The number of participants who met screen time recommendations was not significantly different ($p = 0.33$). There was also no difference in the number of hours of total screen time reported per day.

Discussion

To our knowledge, this is the first study to evaluate self-reported physical activity and screen time in adolescents with pre-dialysis CKD. In addition, this is the first study to compare self-reported physical activity and screen time in adolescents with CKD to that of healthy peers. Prior studies have shown that pediatric patients who progress to ESKD have a significantly higher overall mortality than the general population as well as a particularly increased cardiovascular mortality [3, 7–10]. Studies in adult patients with CKD suggest that physical activity is a strong predictor of cardiovascular mortality, and studies in both pediatric and adult ESKD patients suggest that physical activity may be a modifiable risk factor for cardiovascular disease [13–23, 36–41].

We observed that adolescents with CKD engaged in significantly less physical activity and more screen time than healthy peers. While the proportion of healthy adolescents meeting the current recommendations for physical activity (24.8 %) and screen time (27 %) is low overall, there is a stark disparity in the proportion of adolescents with CKD meeting those same recommendations [29, 31]. The proportion of adolescents with CKD meeting the recommendations for physical activity (13.4 %) was half that of healthy peers. In addition, 98.2 % of adolescents with CKD exceed the recommended 2 h of screen time or less per average school day as compared with 73 % of healthy peers.

Our results cannot readily be explained by the various covariates assessed. While lower eGFR was associated with increased screen time, eGFR was not associated with physical activity. Obesity was associated with decreased physical activity. However, only 17 % of the adolescents in this study were obese at baseline. In addition, studies in pediatric ESKD patients have found that a lower BMI is associated with greater mortality [33]. Children and adolescents with CKD have significant deficits in muscle mass and quality compared to healthy controls [34, 35]. A recent study in the CKiD cohort demonstrated a high burden of fracture risk in this population [44]. In light of our study results, it is concerning that adolescents with CKD have a higher risk of decreased muscle strength, bone deficits, and fracture yet are dramatically less active and more sedentary than healthy peers. It is also concerning that even with a median eGFR above 30 ml/min/ m², engagement in physical activity worsens over time with the proportion of adolescents meeting physical activity requirements decreasing by half in 1 year. A recent study in adults found a decreased risk of developing CKD in veterans with a modest increase in exercise capacity [45]. Given their risk of increased overall mortality, decreased muscle mass, increased fracture, and the possibility to attenuate the development and possibly the progression of CKD with increased physical activity, it is imperative that we determine the driving factors behind the disparity in physical activity and sedentary activity in the pediatric CKD population as compared to healthy peers. Potential driving factors that should be explored include parental influence,

the child's perception of their illness and limitations, geographic location, and other psychosocial factors.

Our study has several limitations. The NHANES data was collected in the 2012 calendar year, while the CKiD data was collected over a longer time frame starting in 2008. However, national trends indicate that physical activity is worsening in children and adolescents, which would only make it less likely to observe such stark disparities with a later cohort of healthy children. The NHANES cohort was aged 12–15 while the CKiD adolescents were aged 12–18. However, the median age in CKiD was 15 years, and age was not significant in the multivariable analysis. The NHANES cohort was 51 % male, while the CKiD cohort is 60 % male. However, the gender breakdown in CKiD is consistent with the established epidemiology of pediatric CKD. The CKiD cohort is predominantly white with a higher household income, which may differ from the NHANES population, which was the comparison group. Finally, the questionnaire utilized did not contain the granular data necessary to make meaningful associations and determine the factors driving the epidemic of sedentary activity in the CKD population. We also had limited longitudinal data and no information on possible psychosocial and other factors underlying the disparities in physical activity and sedentary activity.

In summary, adolescents with CKD engage in significantly less physical activity and more screen time than peers in the United States and physical activity may worsen over time as eGFR declines. Physical activity is likely a modifiable risk factor for future cardiovascular and bone disease in this at risk population. Future studies are needed to understand factors driving the disparity in physical activity between adolescents with CKD and healthy peers and to thereby develop guidelines and effective, practical, and sustainable interventions to increase physical activity and decreased screen time in the pediatric CKD population.

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a) Physical Activity **b) Screen Time**

Fig. 1. Percentage of participants meeting physical activity and screen time recommendations. **a** Physical activity. **b** Screen time. *CKiD* Chronic Kidney Disease in Children, *NHANES* National Health and Nutrition Examination Survey

a) Male participants **b) Female participants**

Fig. 2. Percentage of participants meeting varying levels of physical activity per week. **a** Male participants. **b** Female participants. *CKiD* Chronic Kidney Disease in Children, *NHANES* National Health and Nutrition Examination Survey

Table 1

Baseline characteristics

	CKiD participants
<i>N</i>	224
Age (years)	15 (12, 16)
Male	134 (60 %)
Race	
White	160 (72 %)
Black	43 (19 %)
Other	20 (9 %)
Hispanic	32 (15 %)
Low income	52 (24 %)
Diagnosis	
Glomerular	74 (33 %)
Non-glomerular	150 (67 %)
Estimated glomerular filtration rate (ml/min/1.73 m ²)	41.3 (30.8, 52.3)
Height percentile	25.8 (7.9, 58.4)
Obese (BMI > 95th percentile)	38 (17 %)
Physical Activity	
Days in past 7 reporting 20 min PA	3 (1, 5)
Days in past 7 reporting 30 min PA	2 (1, 5)
Days in past 7 reporting 60 min PA	3 (0, 5)
Met physical activity recommendations	30 (13.4 %)
Days reporting participation in physical education/week	2 (0, 5)
Number of minutes exercising/playing sports in gym class	4 (3, 5)
Number of sports teams played on in past 12 months	1 (0, 2)
Screen time	
Hours of TV watched per day	4 (3, 5)
Hours of video games/computer per day	3 (2, 4)
Total screen time per day	7 (5, 9)
Met screen time recommendations	4 (1.8 %)

Data are presented as *n* (%) or median (inter-quartile range); *PA* physical activity

Table 2

Multivariable logistic regression for covariates of meeting physical activity and screen time recommendations in Chronic Kidney Disease In Children (CKiD) participants

	OR	<i>p</i> value	95 % CI
Met physical activity recommendations			
Age	1.07	0.65	(0.81, 1.40)
Male	1.00	0.98	(0.42, 2.35)
Height percentile	1.00	0.89	(0.99, 1.01)
Low income	1.13	0.81	(0.42, 3.00)
eGFR (ml/min/1.73 m ²)	1.00	0.72	(0.97, 1.02)
Black race	1.54	0.41	(0.55, 4.34)
Glomerular diagnosis	1.48	0.39	(0.60, 3.61)
Obese	0.28	0.11	(0.06, 1.36)
Met screen time recommendations			
Age	1.02	0.97	(0.44, 2.36)
Male	1.80	0.67	(0.12, 26.3)
Height percentile	1.02	0.32	(0.98, 1.06)
Low income	6.20	0.17	(0.45, 85.2)
eGFR (ml/min/1.73 m ²)	1.03	0.30	(0.98, 1.08)
Black race	0.94	0.97	(0.06, 16.0)
Glomerular diagnosis	0.68	0.77	(0.05, 9.56)
Obese	1.26	0.87	(0.08, 19.0)

eGFR estimated glomerular filtration rate, *OR* odds ratio, *CI* confidence interval

Table 3

Multivariable linear regression for covariates of total screen time in Chronic Kidney Disease in Children (CKiD) participants

	β	<i>p</i> value	95 % CI
Total screen time on an average school day			
Age	−0.05	0.67	(−0.28, 0.19)
Male	0.45	0.22	(−0.27, 1.18)
Height percentile	−0.001	0.88	(−0.01, 0.01)
Low income	0.29	0.50	(−0.55, 1.13)
Black race	0.30	0.53	(−0.64, 1.24)
Glomerular diagnosis	0.40	0.31	(−0.38, 1.19)
Obese	1.04	0.04	(0.04, 2.00)
eGFR (ml/min/1.73 m ²)	−0.02	0.03	(−0.05, −0.003)

eGFR estimated glomerular filtration rate

Table 4

Longitudinal analysis of Chronic Kidney Disease in Children (CKiD) participants

<i>N</i> = 136 participants	Visit 10	Visit 20	<i>p</i> value ^a
eGFR (ml/min/1.73 m ²)	40.2 (31.3, 50.6)	36.8 (25.7, 50.6)	< 0.001
Obese	22 (16 %)	27 (20 %)	0.046
Physical activity			
Days in past 7 reporting 20-min PA	3 (2, 5)	3 (1, 5)	0.92
Days in past 7 reporting 30-min PA	2 (0, 4)	2 (0, 4)	0.61
Days in past 7 reporting 60-min PA	3 (1, 5)	2 (0, 4)	0.10
Met physical activity recommendations	20 (14.7 %)	10 (7.5 %)	0.03
Days reporting participation in PE education/week	3 (0, 5)	2 (0, 5)	0.29
Number of minutes exercising/playing in PE sports in gym class	4 (3, 5)	4 (3, 5)	0.51
Sports team participation	78 (57 %)	65 (48 %)	0.02
Screen time			
Hours of TV watched per day	4 (3, 5)	4 (3, 5)	0.43
Hours of video games/computer per day	3 (2, 4)	3 (2, 4)	0.11
Total screen time per day	7 (5, 9)	7 (6, 9)	0.28
Met screen time recommendations	1 (0.7 %)	3 (2.2 %)	0.33

Data presented as *n* (%) or median (inter-quartile range)^a *t* test, Wilcoxon signed-rank, or GEE as indicated; *PA* physical activity, *PE* physical education, *eGFR* estimated glomerular filtration rate