Pedometer-Assessed Physical Activity in Children and Young Adults with CKD

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Summary
Background and objectives Data on physical activity are limited in children with CKD. The objectives of this study were to measure the level and correlates of physical activity in children and young adults with CKD and to determine the association of physical activity with physical performance and physical functioning.

Design, setting, participants, & measurements Physical activity was measured for 7 days using pedometers; physical performance was measured by the 6-minute walk distance (6MWD) and physical functioning with the PedsQL 4.0.

Results Study participants were 44 patients 7–20 years of age who had CKD stage 1–4 (n=12), had ESRD and were undergoing dialysis (n=7), or had undergone kidney transplantation (n=25). Participants were very sedentary; they walked 6218 (interquartile range, 3637, 9829) steps per day, considerably less than recommended. Physical activity did not differ among participants in the CKD stage 1–4, ESRD, and transplant groups. Females were less active than males (P<0.01), and physical activity was 44% lower among young adults (18–20 years) than younger participants (P<0.05). Physical activity was associated positively with maternal education and hemoglobin concentration and inversely with body mass index. Respective 6MWD in males and females was 2 and approximately 4 SDs below expected. Low levels of physical activity were associated with poor physical performance and physical functioning, after adjustment for age, sex, and body mass index.

Conclusions In most participants with CKD, physical activity was considerably below recommended levels. Future studies are needed to determine whether increasing physical activity can improve physical performance and physical functioning.


Introduction
Regular physical activity provides numerous health benefits for people of all ages. In healthy children and young adults, physical activity prevents or delays the development of hypertension, reduces BP and anxiety, increases bone density, promotes physical fitness and weight control (thereby improving body image and mood), and is associated with enhanced academic performance (1). Regular physical activity reduces the risk of developing chronic diseases, such as hypertension, type 2 diabetes, hyperlipidemia, cardiovascular disease, osteoporosis, and obesity (2). There is little research on physical activity in children with CKD or the association of declining renal function and physical fitness. Although patients with renal disease are at a high risk for certain conditions that can be prevented by exercise, exercise is rarely promoted, highlighted, or re-enforced during clinic visits (3).

Physical activity guidelines by the US Centers for Disease Control and Prevention (CDC) recommend that children and young adults engage in at least 60 minutes of physical activity per day; vigorous-intensity aerobic activity should be done at least 3 days per week; and muscle-strengthening activities, such as gymnastics or push-ups, should be included 3 days per week as part of the child’s 60 or more minutes (4). These guidelines do not specifically address children with CKD, but given the high risk for cardiovascular disease and death among adults with CKD, it would be expected that physical activity would be beneficial among youths with CKD. There has been a worldwide decline in aerobic fitness levels and physical activity (5) among children, with a corresponding increasing prevalence of overweight and obese children and young adults (6,7). A few studies have shown that kidney transplant recipients are less active and have lower exercise capacity than healthy children, and that positive physical self-perceptions may be related to increased physical activity (8–11). However, to our knowledge no studies to date have examined physical activity, physical performance, and physical functioning at the same time in children with CKD.

The objective of this study was to measure levels of physical activity, physical performance, and physical functioning in a cohort of children and young adults with CKD stages 1–4, those undergoing hemodialysis or peritoneal dialysis; and those who have had kidney transplantation. In addition, we sought to examine...
potential correlates of physical activity among children with CKD and the association of physical activity with physical performance and self-reported physical functioning.

Materials and Methods

Participants
Children with CKD or ESRD were recruited from the University of California, San Francisco, Pediatric Nephrology Outpatient Clinic and the Children’s Outpatient Hemodialysis Center. Males and females ranging from 7 to 20 years of age with CKD stage 1–4 not yet requiring renal replacement therapy, those undergoing hemodialysis or peritoneal dialysis, and those who had received kidney transplants were eligible to participate. We excluded patients who were hospitalized or had initiated peritoneal dialysis or hemodialysis within the prior month or had received a kidney transplant within the prior 3 months. Parents and patients 18 years of age or older provided written consent for study participation; younger participants also provided their assent. The study was approved by the Committee on Human Research at the University of California, San Francisco, and is registered on ClinicalTrials.gov (NCT01270529).

Study Procedures
At a visit to the Pediatric Clinical Research Center, height and weight were recorded, and body mass index (BMI) was calculated as kg/m². The medical record was reviewed and laboratory data from the last month were abstracted. GFR was estimated using one of two methods: by the modified Schwartz equation (12) for patients with CKD and transplant recipients and by creatinine clearance using 24-hour urine collection and urea kinetics for patients undergoing dialysis.

Physical Activity
Physical activity was measured using a Yamax Digi-walker SW-200 pedometer, which was given to each participant. Participants were instructed to clip the pedometer around the waistline above the hip each morning and to wear the pedometer throughout the day while doing usual activities, except swimming or bathing. They were asked to remove the pedometer before going to bed and to record the day’s step count each night before resetting the device to zero for the next day. Participants also recorded any additional activities, such as canoeing, cycling, and bowling, and these activities were converted to steps using an activity conversion chart included with the pedometer. After 1 week, participants were contacted by telephone and asked to relay the daily step count recorded in their logs, and the average number of steps taken per day over 7 days was calculated.

Physical Performance
Physical performance was measured using the 6-minute walk test (6MWT), which was performed on a 60-foot track in a straight corridor. Participants were instructed to walk back and forth in the corridor, without jogging or running, covering as much distance as possible in 6 minutes. Participants were permitted to slow down, stop, and rest as necessary but were instructed to resume walking as soon as they were able. After 6 minutes, the distance walked was recorded in meters. The test is standardized, with good reliability (13); is easy to administer in clinical settings; and can be used to assess the response to interventions. Values for the 6MWD for the study participants were expressed in SD scores using age- and sex-matched 6MWD values from healthy children (14).

Physical Functioning
Physical functioning was measured using the PedsQL 4.0, a child self-report instrument that measures health-related quality of life in healthy children and for children and young adults with acute and chronic health conditions, according to the following age groups: 2–4, 5–7, 8–12, and 13–18 years (15–18). The multidimensional PedsQL Generic Core Scales measure four essential domains: (1) physical functioning (eight items), (2) emotional functioning (five items), (3) social functioning (five items), and (4) school functioning (five items). We focused on the physical functioning score because we hypothesized that physical functioning is related to physical activity. This score ranges from 0 to 100, with higher scores indicating better functioning.

Statistical Analyses
Statistical analyses were performed using Stata software, version 11. Descriptive statistics (means ± SDs or medians with interquartile ranges [IQRs]) were calculated for all continuous variables, and frequencies and percentages were generated for noncontinuous variables. Univariable and multivariable regression analyses were used to evaluate the patient characteristics associated with average steps taken per day. Candidate covariates, chosen on the basis of associations observed in healthy populations or adult CKD populations, were age, sex, mother’s level of education, diagnosis, estimated GFR (eGFR), BMI, and hemoglobin concentration. Multivariable regression with backward selection was used to assess the association between physical activity (steps/day) and physical performance (6MWD) and physical functioning (PedsQL 4.0).

Results
We approached 54 potential patients. Ten declined (all age 13–17 years) for the following reasons: too fatigued (n=3), too busy (n=3), recent clinical deterioration (n=2), and not interested (n=2). We studied 44 children and young adults (22 males) aged 7–20 years (mean age ± SD, 15.1±3.4 years). Twenty-seven percent of participants had CKD stage 1–4, 16% were undergoing dialysis, and 57% had received a kidney transplant from 3 months to 15 years before the study. Median BMI was 23.4 (IQR, 20.2, 26.9) kg/m², mean eGFR was 59 (IQR, 36, 73) ml/min per m², and mean hemoglobin concentration was 12±1.8 g/dl (Table 1).

Physical activity, measured by pedometer over 7 days, in 90% of the males and 95% of the females was below the recommended levels of 15,000 steps per day for males and 12,000 steps per day for females (19). Males were substantially more active than females, taking a median of 12,000 steps per day for males and 9,122 (IQR, 6,547, 11,951) versus 4,027 (IQR, 2,682, 5,667) steps per day.
Physical performance (6MWD) was below expected levels (14) in the study participants. Overall, the 6MWD was 506 ± 92 m; males walked farther than females (males, 572 ± 92 m; females, 443 ± 55 m; P < 0.001). Comparison with age- and sex-specific normative data (14) showed that the males and females with CKD walked about 2 and 4 SDs less than their peers, respectively. Older children had more impaired 6MWD relative to their peers than did younger children (P < 0.01; Figure 2). Low physical activity was associated with lower 6MWD, even after adjustment for age, sex, and CKD categories (P < 0.001; Table 3).

Mean self-reported physical functioning score for the cohort was 72.7 ± 15, similar to values reported in 85 children undergoing dialysis (74 ± 15) (18) and lower than the scores generally reported in healthy children (87 ± 8) (18,21). Physical functioning was significantly different among the CKD categories (P = 0.05; Table 3); participants with predialysis CKD reported the lowest scores. Low physical activity was associated with poor self-reported physical functioning in multivariable analysis (P < 0.01; Table 2).

**Discussion**

The present results demonstrate that children and young adults with CKD have very low levels of physical activity, as directly measured by pedometer over 7 days, regardless of whether they have predialysis CKD, are undergoing dialysis, or have received a kidney transplant. In our study, females took approximately 5000 fewer daily steps than males, and older children were less active than younger children; the latter difference has also been observed in healthy children (22). In another finding similar to observations in healthy children, we noted that children and youths with college-educated mothers were more physically active than those with less educated mothers, and children with higher BMI were less active than those with lower BMI. Hemoglobin concentration was the only disease-related measure found to be related to physical activity in our cohort. Physical performance, determined by the 6MWD, was poor, with worse performance in older participants. Low levels of physical activity were linearly associated with physical performance and self-reported health-related quality of life after adjustment for age, sex, and BMI. Our results agree with the findings of Hamiwka et al. (10), who reported that 20 pediatric kidney transplant recipients took an average of 928 daily steps. Our results extend those by including children with other stages of CKD; evaluating correlates of physical activity in these children; and addressing the associations among limited physical activity, poor physical performance, and deficits in physical functioning.

In healthy adults, a physical activity goal of 10,000 steps per day is fairly widely accepted (19,23), whereas the appropriate activity target for children is less clear-cut. In an international study, Tudor-Locke et al. proposed a target of 12,000 steps per day for females and 15,000 steps per day for males 6–12 years of age, based on a higher likelihood of obesity among children who took fewer steps than these cut points (20). Adams et al. simultaneously measured steps taken and minutes of activity by intensity in a group of overweight young adults age 11–16 years (13). They found that the targets proposed by Tudor-Locke et al. (19) closely matched the CDC recommendations for moderate to vigorous activity and that a cut point of 11,714 steps per day had 75% sensitivity and 81% specificity for meeting the CDC-recommended guideline of 60 minutes of moderate to vigorous activity per day.
Tudor-Locke et al. recently analyzed physical activity data in a national sample of children who participated in the 2005–2006 National Health and Nutrition Examination Survey (19). Males and females in the United States age 6–11 years averaged approximately 13,000 and 12,000 daily steps, respectively, whereas male and female young adults (age 12–19 years) accumulated fewer steps: 11,000 and 9000, respectively. Overall, 42% of males and 21% of girls in the United States took fewer than 10,000 steps per day and were classified as sedentary. In our cohort, only 10% of males and 5% of girls met CDC-recommended targets for physical activity. Our study suggests that children with CKD are more likely to be sedentary than healthy children, with girls being more sedentary than males.

Although the overall level of physical activity in the present cohort was extremely low, there was still meaningful variation based on patient characteristics. Specifically, we observed higher levels of physical activity in males than in girls and among younger than older children; similar associations have been observed in healthy children (19). In addition, we found that children whose mothers had at least a college education were more active than those whose mothers were less educated, similar to findings in some (24,25) but not all (26,27) studies. A possible reason for this association is that educated mothers are more likely to acquire health-related knowledge and to be aware of physical activity recommendations and cultivate healthy practices. With better education, it is also possible that such mothers have better jobs and greater financial resources that facilitate and promote physical activity.

In the general population, physical activity has been associated with lower prevalence and incidence of cardiovascular risk factors, such as hypertension, type 2 diabetes, obesity, and hyperlipidemia, and lower levels of physical...
activity predict higher mortality (28,29). In the children with CKD we studied, those who were less active had a higher BMI than the more active children, as has consistently been found among cohorts of healthy children and adults (25,30,31). It is unclear, though, whether sedentary behaviors in the children with CKD resulted in a higher BMI or vice versa. Our results support a negative effect of sedentary behavior among children with CKD. First, the higher BMI observed in the less active children can predispose them to worse health outcomes as they become adults. Second, low physical activity levels were associated with worse physical performance and worse self-reported physical functioning even after adjustment for other factors.

We found a significant positive correlation between physical activity and the hemoglobin concentration, after adjustment for age, eGFR, and other factors related to physical activity, suggesting that anemia is a limiting factor for physical activity in children with CKD. Previous studies have shown mixed results with regard to the association between hemoglobin concentration and physical activity or exercise capacity (32). In adults with ESRD, no association was observed between hemoglobin and physical activity measured using accelerometry (33) or determined by questionnaire (32). However, in adult dialysis patients, peak oxygen uptake improved significantly with initiation of erythropoietin-stimulating agents (ESAs) to correct anemia (34). Similarly, a recent meta-analysis showed that in

### Table 2. Univariate and multivariable correlates of physical activity measured in steps per day

<table>
<thead>
<tr>
<th>Variable</th>
<th>Univariate Steps per Day (95% CI)</th>
<th>P Value</th>
<th>Multivariable Steps per Day (95% CI)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, per year</td>
<td>-436 (-824 to -48)</td>
<td>0.03</td>
<td>-310 (-575 to -45)</td>
<td>0.02</td>
</tr>
<tr>
<td>Female</td>
<td>-4898 (-7192 to 2603)</td>
<td>&lt;0.001</td>
<td>-2395 (-4388 to -401)</td>
<td>0.02</td>
</tr>
<tr>
<td>BMI, per kg/m²</td>
<td>-292 (-524 to -60)</td>
<td>0.02</td>
<td>-182 (-356 to -8)</td>
<td>0.04</td>
</tr>
<tr>
<td>Hemoglobin, per g/dl</td>
<td>1162 (476–1848)</td>
<td>&lt;0.01</td>
<td>1039 (539–1339)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Mother with college education (vs. less than college education)</td>
<td>4137 (1699–6576)</td>
<td>&lt;0.01</td>
<td>2738 (915–4561)</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>eGFR/CrCl, per ml/min per 1.73 m²</td>
<td>38 (2–77)</td>
<td>0.06</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Race/ethnicity</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White (reference)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hispanic</td>
<td>-2776 (-5761 to 208)</td>
<td>0.07</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Asian American</td>
<td>3057 (-673 to 6788)</td>
<td>0.10</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>African American</td>
<td>-1520 (-6239 to 3199)</td>
<td>0.5</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

Univariate and multivariable units of measure are steps per day and walking distance in meters/score on PedsQL, respectively. CI, confidence interval; BMI, body mass index; eGFR, estimated GFR; CrCl, creatinine clearance.

*aGFR estimated by the modified Schwartz formula for CKD and transplant recipients. In patients with ESRD, creatinine clearance was calculated using the 24-hour urine collection and urea kinetic modeling and normalized to 1.73 m², thus estimating renal and dialysis clearance.

Figure 2. | Physical performance (6-minute walk distance) in children and young adults with CKD according to age. Light bars represent males and dark bars represent females. SD scores for each participant were calculated using age- and sex-specific normative values (15). The boxes represent the 25th (bottom), 50th (middle), and 75th (upper) percentile for each group. The error bars represent the 5th and 95th percentiles, and the dots represent outliers.
Table 3. Multivariable predictors of physical performance (6-minute walk distance) and physical functioning

<table>
<thead>
<tr>
<th>Variable</th>
<th>Physical Performance on 6MWD (95% CI)</th>
<th>Physical Functioning Score on PedsQL (Child Report) (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Distance (m)</td>
<td>P Value</td>
</tr>
<tr>
<td>Steps, per 100</td>
<td>1.5 (1.1–2.0)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Age, per year</td>
<td>9.1 (4.0–14.3)</td>
<td>0.001</td>
</tr>
<tr>
<td>Female</td>
<td>−59.6 (−99.0 to −20.2)</td>
<td>0.004</td>
</tr>
<tr>
<td>BMI, per kg/m²</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>eGFR/CrCl, ml/min per 1.73 m²</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

Univariate and multivariable units of measure are steps per day and walking distance in meters/score on PedsQL, respectively. 6MWD, 6-minute walk distance; CI, confidence interval; BMI, body mass index; eGFR, estimated GFR; CrCl, creatinine clearance.

extensively validated (40), children with CKD were not included in these studies. Selection bias was another potential limitation because the enrolled patients may have felt “healthier” or been more motivated and thus may have been more physically active than potential patients who declined to enroll. Thus, we believe that the specific estimates of physical activity in our study may not generalize to the United States pediatric CKD population.

However, the associations we observed between patient characteristics and physical activity and between physical activity and 6MWD and self-reported physical function may well generalize to the larger pediatric CKD population.

The cross-sectional nature of our study makes it difficult to draw conclusions about causation, but it is reasonable to think that increasing physical activity would lead to weight loss and improved physical functioning among children with CKD and a lower risk for poor health outcomes in the future. Considering its associated health benefits, exercise should be promoted, highlighted, or reinforced during clinic visits with greater enthusiasm. We believe that the low physical activity in this patient population warrants targeted efforts to increase activity.

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References


