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Assessment of Physical Activity in Chronic Kidney Disease

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Abstract

Background—Physical activity (PA) plays important roles in the development of kidney disease and its complications; however, the validity of standard tools for measuring PA is not well understood.

Study Design—We investigated the performance of several readily-available and widely-used PA and physical function questionnaires, individually and in combination, against accelerometry among a cohort of CKD participants.

Setting and Participants—Forty-six participants from the Seattle Kidney Study, an observational cohort study of persons with CKD, completed the PA Scale for the Elderly, Human Activity Profile (HAP), Medical Outcomes Study SF-36 questionnaire, and the Four Week PA History Questionnaire (FWH). We simultaneously measured PA using an Actigraph GT3X accelerometer over a 14-day period. We estimated the validity of each instrument by testing its associations with log-transformed accelerometry counts. We used the Akaike information criterion to investigate the performance of combinations of questionnaires.

Results—All questionnaire scores were significantly associated with log-transformed accelerometry counts. The HAP correlated best with accelerometry counts ($r^2=0.32$) followed by the SF-36 ($r^2=0.23$). Forty-three percent of the variability in accelerometry counts data was explained by a model that combined the HAP, SF-36 and FWH.

Conclusion—A combination of measurement tools can account for a modest component of PA in patients with CKD; however, a substantial proportion of physical activity is not captured by standard assessments.

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Keywords

chronic kidney disease; physical activity; accelerometry; questionnaires

Introduction

Chronic kidney disease (CKD) is one of the fastest growing chronic diseases in Western society.(1) Physical inactivity plays an important role in CKD development through its relationships with diabetes and hypertension, and in the cardiovascular complications of CKD via chronic inflammation, oxidative stress, and endothelial dysfunction.(2–4) Research into the causes and consequences of physical inactivity in CKD patients is ongoing, and represents a necessary step toward designing future intervention trials that target sedentary behavior as a means to improve the health of this high-risk population.

The evaluation of physical activity levels in CKD studies is hampered by a lack of information regarding the validity and reliability of commonly used tools for measuring individual activity levels. Self-report questionnaires that are typically used to assess physical activity (PA) levels in observational studies may differ in their validity and precision across different populations. Moreover, activity patterns of CKD patients may differ from those of the general population in terms of type, duration, and intensity, such that common self-report instruments used in healthy populations may fail to capture adequate variability due to the lower activity levels common in persons with CKD.(5–9) Resultantly, it is possible that self-reported measures of physical *functioning* or physical *capacity* could be more closely related to variation in activity levels that are not readily ascertained by standard physical activity questionnaires that inquire primarily about exercise and moderate-to-vigorous intensity activities.

The objectives of this study were first to measure and describe objective PA levels using triaxial accelerometry, an objective measure of PA, and second to assess the performance of readily available, commonly used PA and physical function questionnaires, individually and in combination, among a clinic-based cohort of individuals who have stage II-IV CKD.

Materials and Methods

Study participants

The Seattle Kidney Study (SKS) is a clinic-based, prospective cohort study of nondialysis CKD patients based in Seattle, Washington. The SKS began recruiting participants in 2004 from outpatient nephrology clinics at affiliated hospitals of the University of Washington. Eligibility criteria are age >18 years and CKD of any stage not requiring dialysis. Exclusion criteria are current or prior kidney transplantation, dementia, institutionalization, expected to start renal replacement therapy or leave the area within 3 months, participation in a clinical trial, non-English speaking, or inability to undergo the informed consent process. Institutional review boards have continuously approved the SKS since its inception. All subjects undergo written informed consent prior to participation.

For this substudy of PA, we invited 75 consecutive SKS subjects to participate, who were either newly recruited or were returning for a follow-up study visit between June 2010 and June 2011. Participants who had an glomerular filtration rate (eGFR) <15 or >89 ml/min/1.73m², estimated using the 4-variable Modification of Diet in Renal Disease (MDRD) Study Equation,(10) and those who were unable to ambulate were excluded from participation. Participants who required an assistive device for ambulation, such as a cane or walker, remained eligible. Of the 75 invited participants, two refused and 15 were ineligible

(2 participants required a wheelchair, 6 participants had an eGFR <15 ml/min/1.73m², and 7 participants had an eGFR >89 ml/min/1.73m²), leaving 58 subjects who agreed to participate and who provided written, informed consent for this substudy. Of these participants, 12 did not wear the accelerometer for a sufficient amount of time to assess activity (at least 8 hours per day for 7 or more study days) and were excluded from analysis, resulting in a final analytic sample size of 46. The twelve participants who were excluded had similar baseline characteristics as those who were included in the final analyses.

Terminology

Based on the terminology of Mitch and Ikizler,(11) we defined physical activity as a bodily movement that is produced by the contraction of skeletal muscle that increases energy expenditure above basal levels. Physical function was defined as a fundamental component of health status that describes the state of those sensory and motor skills necessary for usual daily activities. Physical capacity was defined as

Accelerometry

During initial assessment, participants were issued an ActiGraph GT3X accelerometer (Actigraph, Fort Walton Beach, Florida), a pager size device powered by a small lithium battery. The accelerometer was attached to an elasticized belt and worn on the right hip. The triaxial accelerometer estimates the duration and intensity of PA by capturing the magnitude of acceleration (intensity) in three dimensions and then summing the magnitudes as counts within a user-determined time interval, referred to as an “epoch”.(12) Validity for this instrument has been previously reported.(13) We selected an epoch length of one minute. (14) A non-wear period was defined as an interval of at least 60 minutes of zero activity counts that contained no more than two minutes of counts between 0 and 100. A non-wear period ended with either a third minute of activity counts greater than zero or a one minute activity count greater than 100.(14) The proportion of wear time spent in sedentary behaviors and in activities of light and moderate-to-vigorous activities were determined by calculating the percent wear time where accelerometry counts met the criterion for a given intensity level. Because there are no widely accepted accelerometer thresholds or “cut-points” by which to evaluate various activity levels in an adult CKD population, we elected to categorize wear-time for each individual by intensity according to maximal oxygen uptake (VO₂max)- rescaled activity counts per minute thresholds that have been previously used to analyze NHANES data. (14, 15) Given that the VO₂max levels in chronic kidney disease are 59.3% of the age-predicted VO₂ max levels in normal controls (16), we rescaled all thresholds by a factor of 0.593. Specifically, time spent at below 59 (100×0.593) activity counts per minute was categorized as sedentary, time spent at 1158 counts per minute was considered light intensity activity, and time spent at 1159 activity counts per minute or greater was considered moderate-to-vigorous activity. Secondly, we employed the Actigraph default cut-points of 100, 101–1952 and >1952 to categorize sedentary, light and moderate-to-vigorous activity.(14)

The criteria for determining compliance with health-related physical activity guidelines were adapted from the American College of Sports Medicine/American Heart Association national guidelines on Physical Activity and Public Health (ACSM/AHA guidelines).(17) Participants were classified as meeting the recommendations if, by accelerometry and by our modified CKD activity level thresholds, they participated in moderate-to-vigorous intensity activities five or more days per week for 30 or more minutes per day, in 10 minute bouts.

Participants were instructed to wear the accelerometer continuously during waking hours for 14 days, removing it only for swimming or bathing. Study coordinators stressed the importance of not deviating from habitual PA levels. Accelerometer data were uploaded and

controlled for quality using the ActiLife Monitoring System (Actigraph, Fort Walton Beach, Florida).

Questionnaires

At the end of the 14-day accelerometry period, participants returned the activity monitor and completed a series of 3 PA and 2 physical function questionnaires. We chose questionnaires that inquired about the past week of activity so that the time period overlapped with the accelerometry data collection period. We also selected questionnaires based on their common use in studies of CKD patients or older adults, and a completion time of 10 minutes or less, to limit subject burden.

Physical activity questionnaires

The Physical Activity Scale for the Elderly (PASE) was designed to measure PA levels among individuals over the age of 65.(18, 19) The PASE inquires about occupational, household and leisure-time activities performed during the past week (matching 7 of the 14 days of accelerometry wear time), using examples of activities commonly performed by older individuals. Each activity is assigned a weight that was derived from a sample of 277 older adults using a combination of accelerometry data, metabolic equivalent-task (MET) values from activity diaries, and global self-reports.(18) The total PASE score was calculated by multiplying the total time spent in each activity (hours per week) by the PASE weight designated to each activity.

The Four Week Physical Activity History Questionnaire (FWH) queries participants as to whether they have engaged in any of the following activities during the prior month: walking for exercise, jogging, biking, aerobics, golf, tennis, swimming, weight training, mowing the lawn, strenuous household chores, treadmill or aerobic machine.(20) Participant responses regarding each type of activity, frequency and duration are used to calculate MET-minutes per week. The intensity of each activity was assigned based on values in the Compendium of Physical Activities.(21) This questionnaire has been validated in the general population against doubly labeled water, heart rate monitoring, changes in maximal oxygen uptake, and accelerometry.(22–26)

To assess time usual spent sitting (hours per week), we selected two questions from the International Physical Activity Long Questionnaire (IPAQ). These questions asked people to report the time they spent sitting at a desk, visiting friends, reading or watching television, in the past 7 days on weekdays and the weekend.(27, 28)

Physical function questionnaires

For the Human Activity Profile (HAP) respondents are asked to indicate, for each of 94 items on the list, whether, given the opportunity or need to do so, they are “still doing”, “have stopped doing” or “never did” the activity. The activities range from very easy (getting in and out of chairs or bed=1) to very strenuous (running or jogging 3 miles in 30 minutes or less=94).(29) To be exact, the HAP is a questionnaire that measures a combination of aspects of both physical activity and physical function. From the responses, we calculated both the maximum activity score (MAS), which corresponds to the number of the most difficult task the subject is still doing, and the adjusted activity score (AAS), which is the difference between the MAS and the number of lower value activities that the respondent has stopped doing.

The Medical Outcomes Study 36-Item Short-Form Health Survey version 2 (SF-36) is a widely-used measure of general functional health and well-being. In order to ascertain

overall physical functioning, we examined the physical component scale (PCS) of SF-36, which is composed of six subscales: physical functioning, bodily pain, general health, role functioning/physical, bodily pain, vitality, and social functioning. Each subscale is scored from 0 to 100, with higher scores indicating better health status or well-being, and then transformed to z scores. The summary measure, PCS, is derived from z scores, such that 50 represents the mean of the general US population.(30)

Covariates

Weight was measured using calibrated scales, height with a wall-mounted tape measure, and waist circumference using a constant-tension tape. Prevalent conditions were determined based on participant responses to questionnaires and hospitalizations that occurred after initial SKS enrollment but prior to the initial assessment for this study, assessed through medical record review. Medication use was assessed by the inventory method; missing medication data were completed by chart review.(31) At each study visit, SKS coordinators collected serum, plasma, and overnight timed urine samples. We defined diabetes by the use of an oral hypoglycemic medication, insulin, fasting blood sugar ≥ 126 mg/dL, non-fasting blood sugar ≥ 200 , or hemoglobin A1c $\geq 6.5\%$. Three seated blood pressure measurements were recorded using an automated sphygmomanometer; the average of the last two readings was retained for analysis. Hypertension was defined by the use of any antihypertensive medication, systolic blood pressure ≥ 140 mmHg, or diastolic blood pressure ≥ 90 mmHg. Medical records were examined to obtain the most recent serum creatinine level (within a maximum of one year preceding study visit). The GFR was estimated using the 4-variable MDRD Study Equation.(10)

Statistical analyses

We computed descriptive statistics on demographics, anthropometric measures, clinical characteristics, medical history and self-reported measures of PA and function levels, stratified by gender. We report continuous variables as means and SD or medians and interquartile range if skewed.

Spearman rank-order correlation coefficients were calculated to examine the relationships between the questionnaire scores. For combinations of categorical and continuous measures, the intraclass correlation coefficient (ICC) was computed.

For validity analyses, in order to satisfy the linear model's assumption of normally distribution error terms, log-transformed accelerometry counts were modeled as the primary dependent variable (gold-standard). In secondary analyses, we examined the percentage of wear time in very light, light or moderate-to-vigorous activities as the dependent variable. We used the Pearson product moment correlation coefficients to assess linear relationships of log-transformed accelerometry counts or percent wear time by intensity level with questionnaire scores, and we constructed scatter plots and locally weighted regression models to investigate the functional form of these associations. Because the correlations did not differ by gender, we present results for the combined cohort.

To determine whether questionnaires might be combined to better account for the variability in accelerometry counts, we performed multivariable linear regression with the counts as the dependent variable and each questionnaire score as independent variables. From each model, we estimated the Akaike Information Criterion (AIC) and used forward selection to build a best-fitting model.(32) The AIC approach quantitatively ranks competing models by estimating the goodness of fit based on the likelihood of the observed data, given the model. AIC favors parsimonious models by including a penalty for the addition of parameters.(32) In comparing different models, the model having the *lowest* AIC value is preferred. In

forward selection, we ranked the questionnaire scores from lowest to highest univariate AIC and added each measure one at a time in that order. We retained only the variables whose inclusion in the model reduced the AIC; if a variable did not reduce the AIC when it was added, it was dropped. Using the AIC has the appeal of not having to set arbitrary criteria for entering and removing variables. The likelihood ratio test comparing each successive model to the nested model without the parameter in question was used to obtain a p-value.

STATA version 11.0 was used for all analyses (College Station, TX).

Results

The mean age of study participants was 55 ± 11 years, mean estimated GFR was 42 ± 15 ml/min·1.73 m², 54% of the cohort were male, 32% were black and 59% had a BMI greater than 30 kg/m² (Table 1). All but one participant was hypertensive, and over half were diabetic. Women were similar to men with respect to age, education, work status and medication use, although they tended to have higher BMI levels, slightly higher proportions of prevalent cardiovascular diseases, and were less likely to report current smoking or alcohol use.

On average, participants completed 11 days of valid accelerometer wear time (Table 2). Using rescaled accelerometry cut-points, ninety-five percent of wear time was spent engaged in sedentary and light activities; accelerometer recording of moderate-vigorous activities was uncommon (less than 5% of wear time). Approximately 6.5% of participants were active at guideline-recommended levels.

There was modest positive correlation between the PASE score and FWH (ICC = 0.41) and between the FWH and IPAQ (ICC=0.28, and an inverse association between PASE score and IPAQ sitting time ($r = -0.25$; Table 3). Among the physical function questionnaires, the HAP MAS score was correlated with the SF-36 PCS ($r=0.61$).

Log-transformed accelerometry counts were associated with HAP-MAS, SF-36, and PASE scores in a roughly linear fashion across the measured range of questionnaire scores (Figure). Scatter plots also revealed a roughly linear association of FWH category with log transformed accelerometry counts.

In univariate linear regression models, all questionnaires scores were statistically significantly associated with log-transformed accelerometry counts in the expected directions (Table 4). However, the predictive capability of the different physical activity instruments was modest at best, based on the r and r -squared. Among the activity questionnaires, PASE score best predicted accelerometry counts (AIC 64.5). The IPAQ sitting time demonstrated the weakest association with accelerometry (r -squared value 0.07). In contrast, the physical functioning instruments performed modestly better, with the HAP-MAS demonstrating the strongest overall predictive capacity for gold standard accelerometry counts (AIC 53.5; 32% of total variation explained).

The FWH, IPAQ, HAP-MAS, HAP-AAS and the SF-36 physical component score were significantly associated with percent time spent in moderate-to-vigorous activities, defined by a re-scaled intensity threshold of greater than 1159 counts per minute. Only the IPAQ and the SF-36 physical component score were significantly associated with percent time spent in light activities. Results were similar when we used conventional Actigraph cut-points (data not shown).

A combination of physical activity and physical functioning questionnaire scores accounted for greater variability in accelerometry counts and improved the goodness of fit of the

statistical model compared to individual questionnaire scores alone. In combination, HAP-MAS, SF-36-PCS, and FWH questionnaires, which collectively can be completed in less than 15 minutes, accounted for an estimated 43% of the variability in accelerometry counts (AIC=50.8).

Discussion

Among a clinic-based cohort of non-dialysis CKD patients, standard physical activity questionnaires were statistically associated with gold-standard accelerometry measurements, but the predictive capacity of these instruments was relatively poor. Validation studies examining correlations between the PASE and the FWH in non-chronically diseased populations have reported stronger agreement than we found in our study. For example, a study of the relationship of accelerometry with the PASE in 20 healthy adult volunteers found that PASE scores were significantly correlated with average accelerometry readings ($r = 0.49$) in the total sample and in those over age 70 years ($r = 0.64$).⁽³³⁾ A similar study in 78 healthy adults found that total activity from the FWH questionnaire correlated only weakly to the accelerometer ($r=0.23$).⁽²⁰⁾

In our study, physical functioning questionnaires better predicted accelerometry counts than physical activity questionnaires, and a combination of three relatively short questionnaires explained 43% of the total variability in accelerometry.

Patients who have CKD are generally less active than individuals in the general population. (5, 34) This has been attributed in part to co-morbid conditions that lead to CKD and in part to muscle weakness and fatigue that develop from retention of metabolic waste products, hormonal disturbances, and oxidative stress. (5, 34) As expected, we found that subjects with CKD had lower scores on all PA questionnaires, compared to available age-matched normative values.^(18, 29, 30) Only 6.5% of participants were meeting current recommended levels of physical activity, using CKD-adjusted accelerometry count thresholds for varying intensity levels. However, a recent study using NHANES data found that fewer than 4% of American adults were meeting the physical activity guidelines according to accelerometry, using the standard activity intensity level thresholds.⁽³⁵⁾ Participants in our study spent an average of 65% of their monitored time engaged in sedentary pursuits. In a large representative population sample in the United States, Matthews et al found that adults over the age of 60 years spent about 60% of their waking time in sedentary behavior.⁽¹⁵⁾

Of the questionnaires evaluated in this study, the HAP – MAS score most closely related to PA measured by accelerometry. This was the case whether we examined accelerometry counts per minute or percent of wear time spent in light or moderate intensity activity. These findings are consistent with previous studies. For example, the maximum activity score of the HAP was also the best predictor of PA as measured by accelerometry in patients with end-stage renal disease (ESRD), explaining 61% of the variability in activity levels.⁽³⁶⁾ The HAP primarily measures the construct of physical capacity, because HAP questions pertain to activities that subjects are still capable of doing, as opposed to activities that they report actually doing.

That a physical capacity questionnaire best predicts total activity in CKD patients may be explained by the fact that CKD participants spend very little time doing activities considered moderate or strenuous based on absolute intensity. As a result, it is possible that self-reported functional capacity provides a better indication of the total amount of activity of an individual. In fact, we found that the physical function questionnaires tested correlated more strongly than both the IPAQ sitting time and the FWH questionnaires with light intensity activities. Activities of daily living such as those assessed on the capacity questionnaires are

both difficult to recall and difficult to capture on standard physical activity questionnaires. (37) However, light activity levels do impact physical function, capacity and health outcomes.(38, 39) The finding that questionnaires assessing physical function or capacity better capture total variation in accelerometer-based measures of energy expenditure than physical activity questionnaires do, in this population, is intriguing. While it should be emphasized that physical function and capacity are distinct constructs from energy expenditure and physical activity, it appears that physical function and capacity questionnaires can explain variability in both lower-intensity activities, which predominate energy expenditure in this population, and moderate-to-vigorous activities. This interesting result might inform the future design of physical activity questionnaires for chronically diseased populations.

The SF-36 PCS was also moderately correlated with accelerometry counts. While the HAP has the advantage of covering a large number of activities, potentially rendering it more sensitive to changes over time when used in longitudinal or interventional studies related to physical functioning, the PCS scale of the SF-36 has the advantage of greater breadth of use in the CKD population, allowing comparison with other groups of CKD patients, healthy individuals, or persons with other chronic diseases. In a study of 40 ambulatory individuals with chronic stroke, the PCS scale of the SF-36 was also found to be significantly correlated with accelerometry-assessed energy expenditure, to a similar extent as in our study population ($r=0.42$). (40)

In combination with the HAP-MAS score, the SF-36 PCS and FWH explained 43% of the variability in accelerometry counts. While the HAP-MAS and PCS scores are highly correlated with each other and the instruments measure similar constructs of physical capacity and function, the FWH is designed to measure exercise and energy expenditure in the previous month.

From a practical standpoint, because none of the measures studied could alone account for a substantial portion of the variance in accelerometry counts, our results suggest, that when measurement of energy expenditure with accelerometry is not possible, the use of a combination of tools to ascertain PA, capacity and function might be useful when designing observational or interventional studies in the CKD population. This can be attained without overburdening participants, as the HAP, SF-36, and FWH require less than 15 minutes for completion.

This study had a number of strengths. These included the use of multiple days of accelerometry measurements, a variety of physical activity and functioning questionnaires and a triaxial accelerometer, allowing for a more accurate assessment of energy expenditure. This study also has several limitations. For example, the sample size was insufficient to evaluate potential age and racial differences in our results. Furthermore, none of the questionnaires used queried light walking, non-exercise activity thermogenesis,(41) and levels of motivation to engage in activities.

In conclusion, the HAP-MAS and SF-36 PCS questionnaires most closely predicted gold standard PA levels in this relatively sedentary, non-dialysis CKD population. An estimated 43% of the variation in accelerometer-based energy expenditure was estimated from a combination of questionnaire scores. These measures encompass a wide-variety of functional and activity constructs that are meaningful in patients with CKD. The sedentary behavior pattern observed in kidney disease patients may represent an attractive target for future intervention studies because even small increases in PA may impact the adverse biochemical environment of CKD. These results will help to guide future studies as to the best methods for assessing PA levels in CKD patients, whose activity patterns may differ

from those of the general population. We recommend gold standard accelerometry when possible or the use of a combination of tools when assessing PA in future studies.

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Figure. Scatterplots and dot plot of physical activity questionnaire scores and accelerometry counts per minute (line=lowess smoother)

Table 1**Participant characteristics**

Variable	Overall (n=46)	Men (n=25)	Women (n=21)
Age (years), mean $\pm$ SD	55 $\pm$ 11	55 $\pm$ 11	56 $\pm$ 11
Black race, n (%)	16 (32)	10 (40)	6 (29)
Systolic blood pressure (mmHg), mean $\pm$ SD	136 $\pm$ 18	135 $\pm$ 18	138 $\pm$ 19
BMI (mg/kg ²), mean $\pm$ SD	32 $\pm$ 8	30 $\pm$ 6	34 $\pm$ 9
Waist circumference (cm), mean $\pm$ SD	107 $\pm$ 18	106 $\pm$ 14	108 $\pm$ 22
Current smoker, n (%)	12 (26)	8 (32)	4 (19)
Current alcohol use, n (%)	15 (33)	12 (48)	3 (14)
Education status, n (%)			
Less than high school	4 (9)	2 (8)	2 (10)
Graduated high school	29 (63)	16 (64)	13 (62)
College degree or higher	13 (28)	7 (28)	6 (29)
Work status, n (%)			
Full-time	7 (15)	3 (12)	4 (19)
Part time	6 (13)	3 (12)	3 (14)
Unemployed	11 (24)	8 (32)	3 (14)
Retired	14 (30)	7 (28)	7 (33)
On disability	8 (17)	4 (16)	4 (19)
Use of assistive device, n (%)	10 (22)	3 (12)	7 (35)
Estimated GFR – MDRD (ml/min/1.73m ²), mean $\pm$ SD	42 $\pm$ 15	42 $\pm$ 17	41 $\pm$ 14
Prevalent Disease, n (%)			
Diabetes	25 (54)	13 (52)	12 (57)
Hypertension	45 (98)	24 (96)	21 (100)
Myocardial infarction or cardiac arrest	8 (17)	3 (12)	5 (24)
Heart failure	13 (28)	4 (16)	9 (43)
Peripheral vascular disease or claudication	11 (24)	5 (20)	6 (29)
Stroke	9 (18)	4 (16)	4 (19)
Angina	10 (22)	6 (24)	4 (19)
Chronic obstructive pulmonary disease	13 (28)	6 (24)	7 (33)
Medication use, n (%)			
ACE-I use	24 (52)	12 (48)	12 (57)
ARB use	15 (33)	9 (36)	6 (29)
Beta-blocker use	24 (52)	12 (56)	10 (48)
Phosphate binder use	8 (17)	3 (12)	5 (24)
Statin use	30 (65)	16 (64)	14 (67)

Abbreviations: ACE-I: angiotensin-converting enzyme inhibitors; ARB: angiotensin-II receptor blockers; BMI: Body mass index; GFR-MDRD: Glomerular filtration rate – Modification of Diet in Renal Disease.

Results presented are mean ($\pm$ SD) unless otherwise noted.

Table 2

Results from Objective and Self-Reported Physical Activity and Function Questionnaires

Measure	Overall (n=46)	Men (n=25)	Women (n=21)
Accelerometer wear data			
Valid days of wear (median (IQR))	11 (9,13)	10 (9,12)	13 (11,14)
Valid hours per valid day (median (IQR))	12 (11,13)	12 (11,13)	13 (12,14)
Counts per minute (median (IQR))	211 (131,292)	262 (202,302)	182 (103,229)
Percent time spent in			
Sedentary behavior ^a (median (IQR))	65 (56,69)	63 (56,67)	66 (60,72)
Light activity ^a (median (IQR))	30 (26,37)	30 (26,37)	30 (26,37)
Moderate to vigorous activity ^a (median (IQR))	5 (3,8)	7 (5,9)	3 (1,5)
Compliance with health-related physical activity guidelines	3 (6.5)	2 (8.0)	1 (4.8)
Physical Activity Questionnaire Scores			
Physical Activity Scale for the Elderly Score	107 (±66)	112 (±69)	102 (±63)
FWH, MET-minutes per week, n (%)			
<180	17 (37)	10 (40)	7 (33)
180 – 540	13 (28)	5 (20)	8 (38)
>540	16 (35)	10 (40)	6 (29)
IPAQ sitting time, hours per day	6.6 (±3.7)	6.4 (±3.6)	6.9 (±3.8)
Physical Function Questionnaire Scores			
Human Activity Profile – Maximum Activity Score	75 (±13)	78 (±12)	71 (±14)
Human Activity Profile – Adjusted Activity Score	57 (±26)	62 (±24)	50 (±28)
SF-36 Physical Component Scale Score	42 (±11)	45 (±9)	40 (±12)

Abbreviations: FWH: Four Week Physical Activity History Questionnaire; SF-36 PCS: Medical Outcomes Study 36-Item Short-Form Health Survey version 2 Physical Component Scale; IQR: Interquartile range; IPAQ: International Physical Activity Questionnaire.

^aBased on the following cut-points: sedentary behavior: <59 activity counts per minute; light activity: 60 – 1158 counts per minute; moderate-to-vigorous: >1159 counts per minute.

Table 3

Intercorrelations among questionnaire scores

Questionnaire score	PASE Score	FWH	IPAQ Sitting time	HAP-MAS	HAP-AAS	SF-36 PCS
PASE Score	1.00					
FWH	ICC=0.41	1.00				
IPAQ Sitting time	-0.25	ICC=0.28	1.00			
HAP – MAS	0.60	ICC=0.23	-0.17	1.00		
HAP – AAS	0.59	ICC=0.17	-0.17	0.87	1.00	
SF-36 PCS Scale	0.44	ICC=0.10	-0.23	0.61	0.68	1.00

Abbreviations: FWH: Four Week Physical Activity History Questionnaire; HAP-MAS: Human activity profile – maximal activity score; SF-36 PCS: Medical Outcomes Study 36-Item Short-Form Health Survey version 2 Physical Component Scale; HAP-AAS: Human activity profile – adjusted activity score; ICC: Intraclass correlation coefficient; IPAQ: International Physical Activity Questionnaire; All correlation coefficients are statistically significant ($p<0.05$).

Table 4
Univariate associations of questionnaire scores with log-transformed accelerometry counts per minute

Measure	Construct measured	N	r	AIC	LR test p-value
Physical Activity Scale for the Elderly Score	Physical Activity	46	0.36	64.5	0.011
Four week physical activity history questionnaire	Physical Activity	46	ICC = 0.28	66.6	0.037
IPAQ sitting time	Sedentary time	46	- 0.26	67.4	0.048
Human Activity Profile – Maximum Activity Score	Physical capacity, Physical function	46	0.56	53.5	<0.001
Human Activity Profile – Adjusted Activity Score	Physical function	46	0.49	58.2	<0.001
SF-36 Physical Component Score	Physical function	45	0.48	58.2	<0.001

Abbreviations: AIC: Akaike information criterion ($=2k - 2\ln(L)$), where k is the number of parameters and L is the maximized likelihood estimate of the model) Lower AICs indicate better model performance; LR: Likelihood ratio ICC: Intraclass correlation coefficient; SF-36 PCS: Medical Outcomes Study 36-Item Short-Form Health Survey version 2 Physical Component Scale; IPAQ: International Physical Activity Questionnaire.

Table 5
Univariate associations of questionnaire scores with percent time spent in light and moderate-to-vigorous activity

Measure	N	% Time spent in light activity			% Time spent in moderate-to-vigorous activity		
		r	AIC	LR test p-value	r	AIC	LR test p
Physical Activity Scale for the Elderly Score	46	0.30	322.9	0.034	0.21	254.9	0.145
Four week physical activity history questionnaire	46	ICC = 0.01	327.1	0.581	ICC=0.38	251.5	0.018
IPAQ sitting time	46	−0.13	320.4	0.007	−0.23	250.1	0.008
Human Activity Profile–Maximum Activity Score	46	0.22	325.1	0.132	0.47	245.7	<0.001
Human Activity Profile–Adjusted Activity Score	46	0.19	325.7	0.191	0.41	248.4	0.003
SF-36 Physical Component Score	45	0.24	321.3	0.013	0.44	241.5	<0.001

Abbreviations: AIC: Akaike information criterion ($=2k - 2\ln(L)$), where k is the number of parameters and L is the maximized likelihood estimate of the model) Lower AICs indicate better model performance; LR: Likelihood ratio; ICC: Intraclass correlation coefficient; SF-36 PCS: Medical Outcomes Study 36-Item Short-Form Health Survey version 2 Physical Component Scale; IPAQ: International Physical Activity Questionnaire.

Based on the following cut-points: light activity: 60 – 1158 counts per minute; moderate-to-vigorous: > 1159 counts per minute.