



A Location-Based Objective Assessment of Physical Activity and Sedentary Behavior in Ambulatory Hemodialysis Patients

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Abstract

Background: Dialysis patients have reduced moderate to vigorous physical activity, and light physical activity. This has been shown in self-reported surveys and objective accelerometer studies. Less attention has been directed toward sedentary behavior, which is characterized by low energy expenditure (≤ 1.5 metabolic equivalents). Furthermore, locations where physical activity and sedentary behavior occur are largely unknown for dialysis patients.

Objectives: The objectives of this study were (1) to determine the minutes per day of moderate to vigorous physical activity, light physical activity, and sedentary behavior for hemodialysis patients; (2) to describe differences in moderate to vigorous physical activity, light physical activity, and sedentary behavior comparing dialysis versus nondialysis days; and (3) to describe the locations where moderate to vigorous physical activity, light physical activity, and sedentary behavior occur using global positioning system (GPS) data.

Design: Cross-sectional study.

Setting: The study was performed at a tertiary care hospital in Nova Scotia, Canada.

Patients: A total of 50 adult in-center hemodialysis patients consented to the study.

Measurements: Physical activity and sedentary behavior were measured with an Actigraph-GT3X accelerometer. Location was determined using a Qstarz BT-Q1000X GPS receiver.

Methods: Minutes of daily activity were described as was percentage of wear time for each activity level across different locations during waking hours. Physical activity intensity, quantity, and location were also analyzed according to dialysis vs nondialysis days.

Results: Forty-three patients met requirements for accelerometer analysis, of whom 42 had GPS data. Median wear time was 836.5 min/day (interquartile range [IQR]: 788.3–918.3). Median minutes of daily wear time spent in sedentary behavior, light physical activity, and moderate to vigorous physical activity was 636 minutes (IQR: 594.1–730.1), 178 minutes (IQR: 144–222.1), and 1.6 minutes (IQR: 0.6–7.7), respectively. Proportion of daily wear time spent in sedentary behavior, light physical activity, and moderate to vigorous physical activity was 78.4% (IQR: 70.7–84.0), 21.5% (IQR: 16.0–26.9), and 0.2% (IQR: 0.1–1.1), respectively. Home was the dominant location for total linked accelerometer-GPS time (59.4%, IQR: 46.9–69.5) as well as for each prespecified level of activity. Significantly more sedentary behavior and less light physical activity occurred on dialysis days compared with nondialysis days ($P \leq .01$, respectively). Moderate to vigorous physical activity did not differ significantly between dialysis and nondialysis days.

Limitations: Small sample size from a single academic center may limit generalizability. Difficult to engage population as less than half of eligible dialysis patients provided consent. Physical activity may have been underestimated as devices were not worn for all waking hours or aquatic activities, and hip-based accelerometers may not capture stationary exercise.

Conclusions: Ambulatory, in-center hemodialysis patients exhibit substantial sedentary behavior and minimal physical activity across a limited range of locations. Given the sedentary tendencies of this population, focus should be directed on increasing physical activity at any location frequented. Home-based exercise programs may serve as a potential adjunct to established intradialytic-based therapies given the amount of time spent in the home environment.



Abrégé

Contexte: Il a été démontré par des enquêtes d'auto-déclaration et des études objectives par accéléromètre que les patients en dialyse pratiquent peu d'activités modérées à vigoureuses et une activité physique légère. Les comportements sédentaires, caractérisés par une faible dépense énergétique ($\leq 1,5$ équivalent métabolique/MET), ont suscité moins d'intérêt. De plus, les endroits où l'activité physique et le comportement sédentaire sont pratiqués sont en grande partie inconnus des patients dialysés.

Objectifs: 1) Déterminer le nombre de minutes par jour d'activité physique modérée à vigoureuse, d'activité physique légère et de sédentarité chez les patients hémodialysés. 2) Décrire les différences d'activité physique modérée à vigoureuse, d'activité physique légère et de comportement sédentaire en comparant les journées de dialyse aux journées sans dialyse. 3) Recenser les endroits où les activités physiques modérées à vigoureuses, les activités physiques légères et les comportements sédentaires se produisent à l'aide des données du système de positionnement global (GPS).

Type d'étude: Étude transversale.

Cadre: L'étude a été réalisée dans un hôpital de soins tertiaires en Nouvelle-Écosse (Canada).

Sujets: Au total, 50 adultes hémodialysés en centre ont accepté de participer à l'étude.

Mesures: Le niveau d'activité physique et les comportements sédentaires ont été mesurés à l'aide de l'accéléromètre Actigraph-GT3X. Les lieux ont été déterminés à l'aide d'un récepteur Qstarz BT-Q1000X GPS.

Méthodologie: Le nombre de minutes d'activité quotidienne a été exprimé en pourcentage de temps de port de l'appareil pour chaque type d'activité, à différents endroits, pendant les heures d'éveil. L'intensité, la quantité et la localisation de l'activité physique ont également été analysées selon qu'il s'agissait ou non d'une journée de dialyse.

Résultats: Quarante-trois patients remplissaient les conditions requises pour l'analyse par accéléromètre, dont 42 disposaient de données GPS. Le temps de port médian était de 836,5 minutes/jour (EIQ: 788,3-918,3). La médiane du nombre de minutes de port quotidien passées en période de sédentarité, d'activité physique légère ou d'activité modérée à vigoureuse était de 636 minutes (EIQ: 594,1-730,1), de 178 minutes (EIQ: 144-222,1) et de 1,6 minute (EIQ: 0,6-7,7), respectivement. La proportion du temps de port quotidien passé en comportement sédentaire, en activité physique légère et en activité physique modérée à vigoureuse était de 78,4 % (IQR 70,7-84,0), 21,5 % (IQR 16,0-26,9) et 0,2 % (IQR 0,1-1,1), respectivement. Le temps total pour le duo accéléromètre-GPS (59,4 %; IQR 46,9-69,5) et chacun des niveaux d'activité prédéfinis a été majoritairement enregistré au domicile. Les périodes de sédentarité et de faible activité physique ont été nettement plus observées les jours de dialyse en comparaison des jours sans dialyse ($P \leq ,01$). L'activité physique modérée à vigoureuse n'a pas varié de façon significative, qu'il s'agisse ou non d'un jour de dialyse.

Limites: La généralisation des résultats est limitée par la petite taille de l'échantillon et le fait que les sujets provenaient d'un seul centre. Aussi, le recrutement des sujets est difficile, moins de la moitié des patients admissibles a donné son consentement. Enfin, l'activité physique pourrait être sous-estimée puisque les appareils n'étaient pas portés pendant toutes les heures d'éveil ou lors des activités aquatiques, et qu'il est possible que l'accéléromètre, porté à la hanche, n'ait pas enregistré pas les exercices stationnaires.

Conclusion: Les patients hémodialysés en centre sont très largement sédentaires et pratiquent une activité physique minimale dans un nombre limité d'endroits. Compte tenu de cette tendance, il convient de mettre l'accent sur l'augmentation de l'activité physique dans les lieux fréquentés par ces patients. Étant donné le temps passé à la maison, un programme d'exercices à domicile pourrait servir d'adjuvant potentiel aux traitements intradialytiques établis.

Keywords

physical activity, sedentary behavior, hemodialysis, accelerometer, global positioning system, GPS

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What was known before

Decreased physical activity and increased sedentary behavior are associated with poor health outcomes in the general population. Hemodialysis patients have considerably reduced physical activity compared with nondialysis populations but less is known about their sedentary tendencies and locations where these behaviors occur.

What this adds

This study shows that hemodialysis patients exhibit minimal physical activity, and substantial sedentary behavior, across a limited range of locations. Given the sedentary tendencies of this population, future studies should focus on increasing physical activity at any location frequented. Home-based exercise programs may serve as a potential adjunct to intradialytic-based therapies given the considerable amount of time spent in the home environment.

Introduction

Patients receiving dialysis have reduced levels of physical activity and increased sedentary behavior compared with the general population.^{1,2} This is associated with a negative impact on survival for those receiving dialysis,³⁻⁶ whereas habitual physical activity may confer a survival advantage^{3,4,6-8} and improved health-related quality of life³ among in-center hemodialysis patients.

Questionnaire-based assessments have shown low self-reported physical activity in hemodialysis patients.^{3,4} Although important, these evaluations require introspective ability and may suffer from response bias which may limit objectivity of the data collected.⁹ They also may not accurately capture details such as intensity, timing, and duration of physical activity. As such, there has been a greater emphasis on the use of objective accelerometer-based assessments of physical activity in dialysis populations.^{7,8,10,11} Accelerometers can further stratify physical activity into moderate to vigorous physical activity, and light physical activity, based on number of counts per minute. Accelerometer-based studies confirm that dialysis patients are less active compared with healthy controls¹ and renal transplant recipients.¹² Much less is known about the prevalence of sedentary behavior in hemodialysis patients using objective accelerometer-based assessment. This is especially relevant when considering the association between sedentary behavior and poor outcomes, including cardiovascular disease and all-cause mortality, in other nondialysis patient populations.¹³ The role of hemodialysis treatment also needs to be considered when assessing sedentary behavior, as prior studies have shown lower physical activity on dialysis days compared with nondialysis days.¹⁰

Identifying locations where physical activity and sedentary behavior occur is an essential step in developing interventions targeting these behaviors in the hemodialysis

population. Previous studies have shown that the majority of moderate to vigorous physical activity in the general population occurs outside of the home environment.^{14,15} However, this population does not have the same degree of comorbidity and frailty as individuals who require in-center hemodialysis which limits the generalizability of these findings. Up to 67% of dialysis patients met the definition of frailty including poor self-reported physical functioning, fatigue/exhaustion, and undernutrition in a recent study¹⁶ which suggests their physical activity tendencies may not mirror those of the general population. Determining where physical activity and sedentary behavior occur for hemodialysis patients is the first step to designing successful interventions which modify these behaviors. To date, objective assessments of real-world locations where physical activity and sedentary behavior occur have not been examined in a hemodialysis population.

Therefore, in a cohort of in-center hemodialysis patients, the purpose of this study was to (1) objectively determine the minutes per day of moderate to vigorous physical activity, light physical activity, and sedentary behavior; (2) describe differences in moderate to vigorous physical activity, light physical activity, and sedentary behavior comparing dialysis versus nondialysis days; and (3) describe the locations where moderate to vigorous physical activity, light physical activity, and sedentary behavior occur using global positioning system (GPS) data. We hypothesized that hemodialysis patients would exhibit a low level of moderate to vigorous physical activity and high sedentary behavior given the results of prior questionnaire-based activity assessments and that sedentary behavior would be higher on dialysis days. We also hypothesized that physical activity would occur most frequently in the home environment given the frailty of this population.

Methods

Population

We analyzed a cross section of chronic in-center hemodialysis patients at a large tertiary care institute (Queen Elizabeth II Health Science Centre, Halifax, NS). Recruitment occurred over a 3-month period between June 1, 2017, and August 31, 2017. We chose a convenience sample of any patient who consented to participate and satisfied inclusion and exclusion criteria. The Nova Scotia Health Authority Research Ethics Board (#1022204) approved this study. All participants provided written informed consent.

Inclusion/Exclusion

Eligible patients were ≥ 18 years old, receiving in-center hemodialysis for at least 3 months, and could read and write in English, to ensure accurate usage of the accelerometer and GPS unit. We excluded any patient who was admitted to

hospital, receiving acute dialysis with anticipation of renal recovery, those who were unable to participate due to medical or physical limitation (bed ridden, amputation without prosthesis, wheelchair bound, or unable to ambulate despite gait aids), or those that were deemed by their primary nephrologist to be unlikely to collect the requisite number of days of accelerometer data required for the study.

Procedure

Patients were provided instruction on accelerometer and GPS use by study coordinators and asked to wear both devices continuously (from waking until bed) for a duration of 9 days. We chose this duration to account for incomplete data capture on the days that the devices were collected and returned with a goal of 7 complete days of accelerometer/GPS wear time. Furthermore, this timeline allowed for 3 dialysis sessions to be captured representing a typical week for hemodialysis patients. The accelerometer ($3.8 \times 3.7 \times 1.8$ cm) was attached to a belt and worn at the hip while the GPS unit ($7.2 \times 4.6 \times 2$ cm) was stored in a belt pouch on the contralateral hip. Devices were not worn overnight or during water-based activities.

Accelerometer-Measured Physical Activity and Sedentary Behavior

Physical activity and sedentary behavior were measured using the Actigraph GT3X accelerometer, which has been shown to be a valid and reliable tool.^{17,18} Data were collected in 5-second epochs and reintegrated to a 60-second epoch prior to being cleaned using Actilife 6.10.2 software (Actigraph, LLC). Nonwear time was defined as at least 90 consecutive minutes of zero counts, with allowance for up to 2 minutes of nonzero counts provided there are no counts recorded in the 30 minutes upstream and downstream from the nonzero interval.¹⁹ A valid day was subsequently defined as ≥ 10 hours of wear time. Definitions of moderate to vigorous physical activity, light physical activity, and sedentary behavior were activities that require ≥ 3 metabolic equivalents (METs), 1.6 to 2.9 METs, and ≤ 1.5 METs in a sitting, reclining, or lying posture, respectively. Examples include raking the lawn (moderate to vigorous physical activity), watering plants (light physical activity), and watching TV on the couch (sedentary behavior). The Troiano et al²⁰ cut-points were used to define sedentary behavior (< 100 counts per minute), light physical activity (100-2019 counts per minute), and moderate to vigorous physical activity (≥ 2020 counts per minute).

Geographical Locations of Physical Activity and Sedentary Behavior

Locations where physical activity and sedentary behavior occurred were mapped objectively using the Qstarz BT-Q1000X

GPS data logger, which provided the date, time, speed, latitude, and longitude information every 5 seconds (ie, to be in sync with the accelerometer data). This device is accurate within a 3-meter distance of the participant and has been shown to be a valid tool.^{15,21} The device was capable of recording up to 24 hours of location data per day but needed to be recharged by patients on a nightly basis. Using the Actilife 6.10.2 software, the 60-second epoch accelerometer data were linked to the 5 second GPS data and imported into ArcGIS 10.2.2. The linked data were then geocoded using OpenStreetMaps and World Imagery base maps in addition to the Google Maps add-in, which provided a street view when needed. Each minute of linked data was coded into home, a residence that was not home (eg, a neighbor's house), a hospital or medical clinic, a street or sidewalk, a walking path or trail, a food or shopping area (eg, a restaurant, a mall), greenspace and/or recreation area (eg, a park, fitness facility, field, etc), a service building (eg, a bank, car dealership, a movie theater, etc), and transportation (eg, driving 80 miles/hour on the highway while sedentary), and error (eg, GPS points in the ocean).

Patient Characteristics

Baseline demographics were obtained following a questionnaire and assessment of patient electronic records and paper charts at the time of consent.

Analysis

Baseline demographics and characteristics for the entire study cohort were reported using descriptive statistics. Mean with standard deviation, median with interquartile range, and number with percent were used for continuous normal, non-normal, and categorical baseline variables, respectively. Time spent in sedentary behavior, light physical activity, and moderate to vigorous physical activity was averaged across valid days to give total minutes per day at each activity level and reported as medians with interquartile ranges. The proportion of time spent in each state was reported as a percentage of total wear time. In the primary analysis and consistent with recommendations, at least 4 valid days were required for reporting of accelerometer data and for GPS linkage.²⁰ The amount of moderate to vigorous physical activity accumulated in bouts of ≥ 10 minutes was used to determine whether individuals were meeting the Canadian physical activity guidelines (weekly sum ≥ 150 minutes of moderate to vigorous physical activity in bouts of ≥ 10 minutes).²² To count as a bout, 10 consecutive minutes of observations had to exceed the moderate to vigorous physical activity cut-point, with allowance for a maximum of 2 observations falling below the cut-point during that period (ie, 8 out of 10 minutes had to be above the cut-point).²³ If patients had 1 to 6 valid days, their average daily moderate to vigorous physical activity was multiplied by 7 to obtain a weekly sum.²³ For the analysis evaluating differences in time spent in sedentary

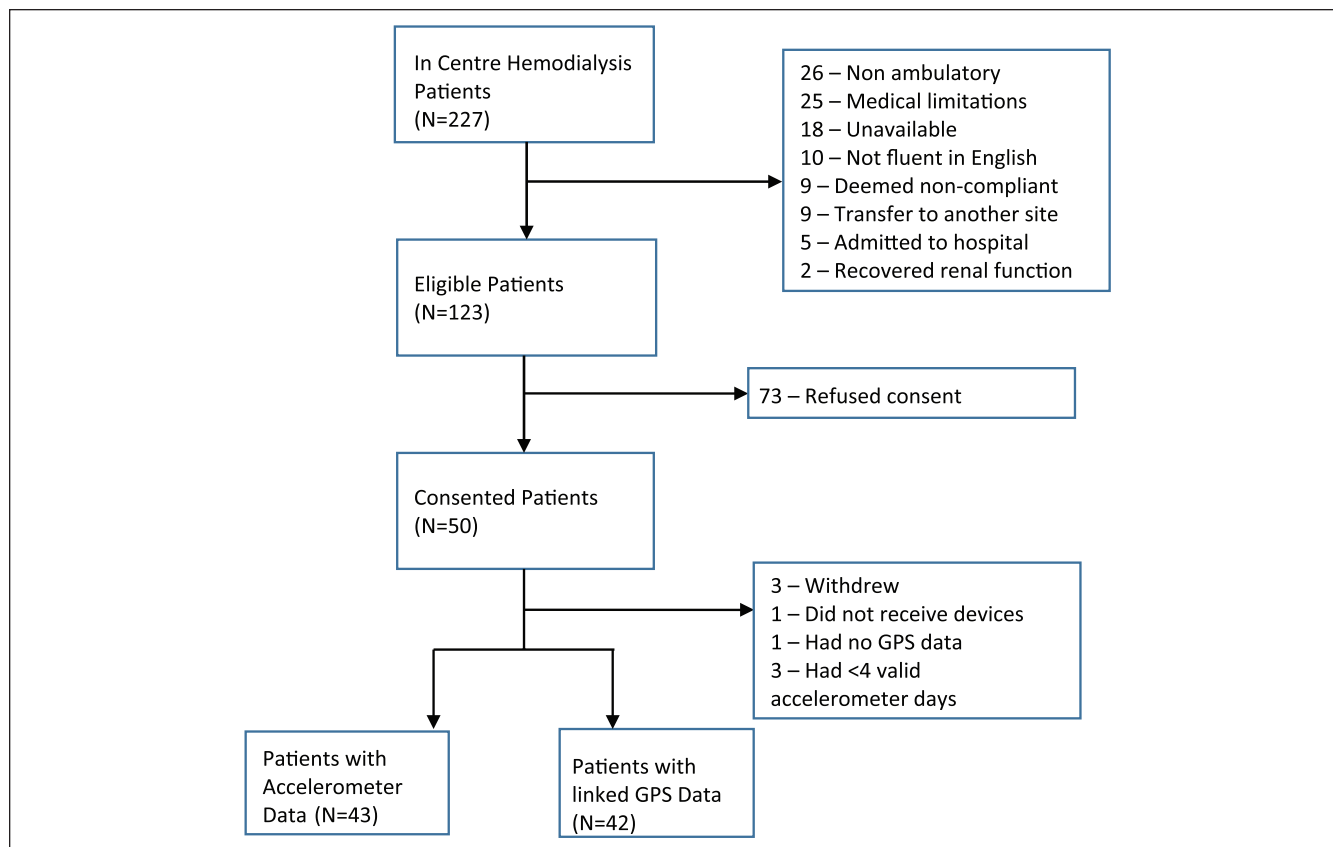


Figure 1. Flow chart depicting final study populations.

Note. GPS = global positioning system.

behavior, light physical activity, and moderate to vigorous physical activity comparing dialysis with nondialysis days, we reported time and percentage of daily wear time in each activity state. Unadjusted comparisons were made using the Wilcoxon rank sum test. The percent of total linked time at a given location was reported for overall accelerometer use and each activity level. Similar to above, the percent of daily linked time at a given location was compared for dialysis versus nondialysis days using the rank sum test. For all analyses, a $P < .05$ was used as the threshold for statistical significance. All statistical analyses were conducted using Stata 14 software (Stata Statistical Software: Release 14, College Station TX: StataCorp LP).

Results

Baseline Characteristics

A total of 50 patients consented to participate in the study, 3 of whom withdrew (Figure 1). Baseline characteristics of the remaining 47 patients are noted in Table 1. The majority of our cohort was male (74%) and the mean age was 61 ± 15 years. Seventy-one percent of our cohort had been on dialysis for >1 year. A central venous catheter was the most common dialysis access. The most common cause of end-stage renal

disease was diabetic nephropathy (43%), followed by glomerulonephritis (30%) and polycystic kidney disease (13%).

Accelerometer Data

Of the 47 consenting patients, 1 did not receive the device (Figure 1). A total of 43 of 46 patients obtained 4 or more valid accelerometer days. The median accelerometer wear time was 836.5 min/day (interquartile range [IQR]: 788.3-918.3) equating to approximately 14 hours of daily wear time. In those with ≥ 4 valid accelerometer days, 636 min/day was spent sedentary (IQR: 594.1-730.0), 178 min/day was spent performing light physical activity (IQR: 144.0-222.1), and 1.6 min/day was spent on moderate to vigorous physical activity (IQR: 0.6-7.7) (Table 2). Only 2 people met the Canadian physical activity guidelines recommending ≥ 150 min/week of moderate to vigorous physical activity obtained in bouts of ≥ 10 minutes. Of the 289 individual valid accelerometer days, 139 occurred on a dialysis day and 150 on a nondialysis day. Comparisons of total daily minutes and proportion of daily time spent in each activity state for dialysis and nondialysis days are noted in Table 3. There was significantly less sedentary behavior on nondialysis days compared with dialysis days (601 min/day, IQR: 514-706; 701 min/day,

Table 1. Baseline Patient Characteristics.

Variable, N (%) unless noted	N = 47
Age, mean (SD)	61 ± 15
Sex	
Male	35 (74)
Female	12 (26)
BMI, median (IQR)	27.5 (25-32)
Employment	
Any employment	7 (15)
Unemployed/disability/retired	39 (85)
Salary	
<\$20,000	9 (20)
\$20,000-\$75,000	22 (50)
>\$75,000	13 (30)
Years on dialysis	
<1	14 (30)
1-5	29 (62)
>5	4 (9)
Dialysis access	
Central venous catheter	33 (70)
Arteriovenous fistula	14 (30)
Dialysis schedule	
3× weekly	45 (96)
4× weekly	2 (4)
ESRD etiology	
Diabetes	20 (43)
Glomerulonephritis	14 (30)
PKD	6 (13)
Other	7 (15)
Comorbidities	
Diabetes	22 (47)
Coronary disease	16 (34)
Heart failure	10 (21)
Pulmonary disease	14 (30)
Peripheral vascular disease	5 (11)
Bloodwork, mean (SD)	
Hemoglobin	107.6 g/l ± 11.7
Albumin	33.3 g/l ± 3.4

Note. Missing: Employment (n = 1); Salary (n = 3). BMI = body mass index; IQR = interquartile range; ESRD = end-stage renal disease; PKD = autosomal dominant polycystic kidney disease.

IQR: 604-762; $P \leq .01$) and more light physical activity (192 min/day, IQR: 148-256; 150 min/day, IQR: 116-201; $P \leq .01$). Daily moderate to vigorous physical activity did not differ significantly between nondialysis and dialysis days (2 min/day, IQR: 0-8; 1 min/day, IQR: 0-4; $P = .2$).

Global Positioning System Data

Of the 47 consenting patients, 1 did not receive a GPS device and 1 did not collect any GPS data leaving an eligible cohort of 42 patients with linkable GPS data (using a cut-off of ≥ 4 valid accelerometer days; Figure 1). The

Table 2. Accelerometer Data for Patients With ≥ 4 Valid Accelerometer Days.

	≥ 4 valid days (N = 43)
	Median (IQR)
Accelerometer wear time	
Minutes/day	836.5 (788.3-918.3)
Sedentary behavior	
Minutes/day	636.0 (594.1-730.0)
% of wear time/day	78.4 (70.7-84.0)
LPA	
Minutes/day	178.0 (144.0-222.1)
% of wear time/day	21.5 (16.0-26.9)
MVPA	
Minutes/day	1.6 (0.6-7.7)
% of wear time/day	0.2 (0.1-1.1)
MVPA guidelines	
≥ 150 minutes/week in bouts of ≥ 10 minutes N (%)	2 (5)

Note. Values reported in median and interquartile range unless otherwise noted. IQR = interquartile range; LPA = light physical activity; MVPA = moderate to vigorous physical activity.

percent of accelerometer data linked to GPS for sedentary behavior, light physical activity, and moderate to vigorous physical activity was 92.9%, 92.8%, and 97.5%, respectively. Five patients had no moderate to vigorous physical activity linked to GPS data and the median moderate to vigorous physical activity was 0.8 min/day in this group. The proportion of overall accelerometer use, sedentary behavior, light physical activity, and moderate to vigorous physical activity time for each coded GPS location is noted in Table 4. The majority of accelerometer wear time occurred in the home followed by hospital and transport. Home was also the dominant category across all levels of physical activity. Median percentage of sedentary behavior, light physical activity, and moderate to vigorous physical activity time in the home environment was 57.7%, 63.3%, and 60.3%, respectively. Hospital was the next most common location for sedentary behavior accounting for 17.8% of total sedentary time, whereas hospital and transportation were similar for light physical activity and moderate to vigorous physical activity. Minimal moderate to vigorous physical activity occurred outside of the home. The percent of daily linked time at a given location for different activity levels stratified by dialysis days can be seen in Supplementary Table 1. On dialysis days, there was significantly more daily sedentary time spent in the hospital compared with nondialysis days (36.2% vs 0%; $P \leq .001$), whereas more sedentary time occurred at home on nondialysis days compared with dialysis days (76.6% vs 44.4% $P \leq .001$). A summary of accelerometer and GPS findings is shown in Figure 2.

Table 3. Accelerometer Data Stratified by Dialysis Day (Yes/No) for Patients With ≥ 10 Hours Daily Wear Time.

	Dialysis day N = 139	Nondialysis day N = 150	P value
	Median (IQR)	Median (IQR)	
Accelerometer wear time			
Minutes/day	873 (767-976)	817.5 (736-922)	.01
Sedentary behavior			
Minutes/day	701 (604-762)	601 (514-706)	<.01
% of wear time/day	81.8 (75.5-87.0)	75.8 (66.5-82.0)	<.01
LPA			
Minutes/day	150 (116-201)	192 (148-256)	<.01
% of wear time/day	18.1 (13.0-22.6)	23.4 (17.3-32.1)	<.01
MVPA			
Minutes/day	1 (0-4)	2 (0-8)	.20
% of wear time/day	0.13 (0-0.51)	0.19 (0-0.88)	.19

Note. Values reported in median and interquartile range unless otherwise noted. $P < .05$ considered statistically significant. IQR = interquartile range; LPA = light physical activity; MVPA = moderate to vigorous physical activity.

Table 4. Locations of Physical Activity as a Percentage of Linked Accelerometer and GPS Data in Those With ≥ 4 Valid Accelerometer Days.

Location	Median % (IQR)
Overall accelerometer use (N = 42)	
Home	59.4 (46.9-69.5)
Hospital	15.3 (12.0-17.8)
Transportation	7.7 (5.3-11.5)
Food/shopping	3.5 (2.1-6.5)
Residence (not home)	1.3 (0.2-4.6)
Service buildings	1.0 (0-3.7)
Street/sidewalk	0.6 (0.1-1.8)
Greenspace/recreation	2.7 (0.9-5.1)
Path/trail	0.0 (0-0)
Sedentary behavior (N = 42)	
Home	57.7 (41.9-68.5)
Hospital	17.6 (13.5-21.7)
Transportation	7.9 (5.2-11.1)
Food/shopping	3.8 (2.1-7.7)
Residence (not home)	1.3 (0.1-4.5)
Service buildings	0.8 (0.1-3.6)
Street/sidewalk	0.5 (0.1-1.5)
Greenspace/recreation	0.4 (0-3.1)
Path/trail	0 (0-0)
Light physical activity (N = 42)	
Home	63.3 (46.2-76.3)
Hospital	6.8 (5.2-10.3)
Transportation	8.0 (6.0-14.8)
Food/shopping	0.8 (0-3.9)
Residence (not home)	1.2 (0.4-3.8)
Service buildings	0.4 (0-3.9)
Street/sidewalk	0.6 (0-2.0)
Greenspace/recreation	5.3 (2.4-10.2)
Path/trail	0 (0-0.1)

(continued)

Table 4. (continued)

Location	Median % (IQR)
Moderate to vigorous physical activity (N = 38)	
Home	60.3 (37.5-80.0)
Hospital	6.2 (0-16.7)
Transportation	2.4 (0-20.8)
Food/shopping	1.3 (0-14.3)
Residence (not home)	0 (0-0.3)
Service buildings	0 (0-0)
Street/sidewalk	0 (0-0)
Greenspace/recreation	0 (0-0)
Path/trail	0 (0-0)

Note. Median % of wear time at "error" location 0% for all activity levels. GPS = Global positioning system; IQR = interquartile range.

Discussion

In this study, we linked accelerometer and GPS data to describe physical activity, sedentary behavior, and where these activities occur in a cohort of ambulatory, in-center hemodialysis patients. We found that hemodialysis patients exhibit minimal moderate to vigorous physical activity and substantial sedentary behavior. Furthermore, we found that irrespective of activity level, all behaviors seemed to occur across a limited range of locations including home, transportation, and hospital. Finally, we found differences in the types and locations of activity when comparing dialysis with nondialysis days; the proportion of time spent in a sedentary state was significantly higher on dialysis days compared with nondialysis days.

Our findings that dialysis patients exhibit minimal moderate to vigorous physical activity are consistent with other accelerometer-based studies of dialysis patients including a recent study which found that hemodialysis patients did on

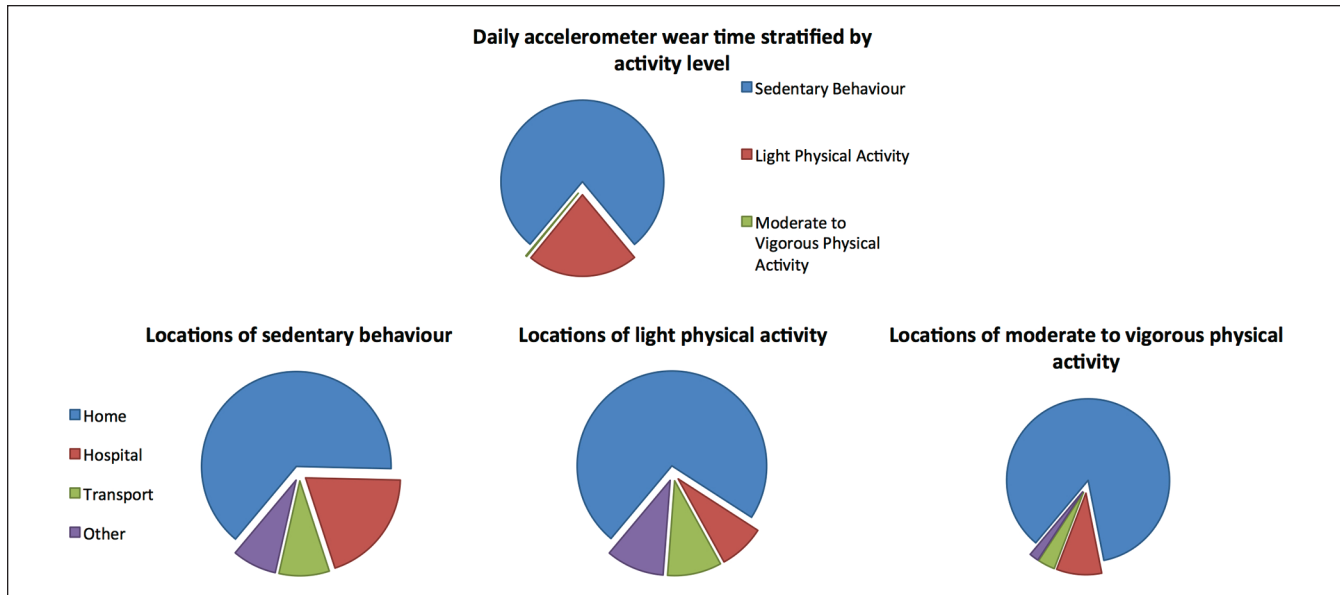


Figure 2. Daily accelerometer wear time stratified by activity level and locations where each activity level occurred. Note. Exact proportions were not included as all values were medians.

average only 5.7 minutes of moderate to vigorous physical activity per day.⁹ Only 4% of our study participants met the Canadian physical activity guidelines recommending ≥ 150 min/week of moderate to vigorous physical activity. This value is substantially lower than a recent Brazilian study which reported 35% of their hemodialysis cohort was able to achieve ≥ 150 min/week of moderate to vigorous physical activity.¹¹ The discrepancy in these values is likely a result of following Canadian guidelines requiring moderate to vigorous physical activity to be acquired in bouts of ≥ 10 minutes, whereas the Brazilian study summed moderate to vigorous physical activity of any duration in patients who did on average <15 min/day of moderate to vigorous physical activity.

There are considerably fewer studies regarding objective assessment of sedentary behavior in hemodialysis patients. A previous study using pedometers and minimum steps per day demonstrated increased sedentary behavior in hemodialysis patients.²⁴ Other studies have used accelerometers to show that hemodialysis patients are more sedentary than age- and sex-matched controls,² and kidney transplant recipients¹² based on daily step count. While informative, a limitation of these studies is that they defined sedentary behavior using a threshold of <5000 steps/day. This method dichotomizes sedentary behavior without capturing other important details such as total time and percentage of device wear time spent in a sedentary state. A recently published cross-sectional analysis describing accelerometer-measured sedentary time in the Canadian population showed sedentary behavior increased as estimated glomerular filtration rate (eGFR) declined and those in the lowest eGFR cohort (<45 mL/min/m²) spent upward of 80% of total wear time in a sedentary state.²⁵ Although comparable, there are several possible reasons why the proportion of sedentary behavior time in our hemodialysis

cohort was lower. First, our cohort was younger (61 vs 71 years) and may be more active. Second, our upper limit for defining sedentary behavior was 0.5 METs lower than the criteria used in the cross-sectional analysis. Thus, people who performed light physical activity in our study may be been classified as sedentary in the cross-sectional analysis. Third, prior studies have shown an association between male sex and increased physical activity and our cohort contained a higher percentage of male participants (74% vs 58%).³ Finally, our cohort was ambulatory and excluded individuals with forms of mobility impairment not limited to wheelchair dependence. We also found that hemodialysis patients exhibited more sedentary behavior and less light physical activity, and moderate to vigorous physical activity on dialysis days compared with nondialysis days, which is consistent with previous studies.¹¹ This was not unexpected given the stationary time required for hemodialysis as well as postdialysis fatigue often reported by patients.²⁶

Sedentary behavior in our population is comparable with reported values in other frail populations. A study of sedentary behavior in a cohort of community dwelling adults ≥ 65 years old who were 3 to 12 months post hip fracture showed that up to 77% of daily accelerometer wear time was spent sedentary.²⁷ Another study involving patients beginning cardiac rehabilitation found that 71% of daily accelerometer wear time was spent in a sedentary state.²⁸ Both of these populations are also burdened by comorbidity and frailty, similar to in-center hemodialysis patients.

Studies have shown an association between sedentary behavior and all-cause mortality using objective accelerometer data in the general population.²⁹ In dialysis, sedentary behavior is also associated with an adjusted increased risk of death at 1 year (HR: 1.62; 95% CI: 1.16-2.27).⁵

These studies illustrate the implications of sedentary behavior and, in concert with the high prevalence of sedentary behavior in our study, potentially underscore the need for future studies focusing on reducing sedentary behavior in hemodialysis patients.

To our knowledge, linking physical activity to real-world locations using objective GPS data has not been done in this population. Locations obtained with GPS methodology should be more accurate than subjective questionnaire-based location assessments. A striking finding from our GPS data is the extensive proportion of time spent at home across all activity levels. While the majority of moderate to vigorous physical activity occurred in the home environment, the total minutes per day of moderate to vigorous physical activity was minimal. Thus, it may prove prudent to focus on any location to increase moderate to vigorous physical activity given how little is done overall. Potential benefits of increasing moderate to vigorous physical activity outside of the home environment include prevention of social isolation and strengthen support networks which may help with exercise sustainability.

The vast majority of sedentary behavior occurred in the home environment followed by the hospital and transportation. Appreciating that both time in hospital and transportation was higher on dialysis days, we suspect the high proportion of sedentary behavior in these locations was directly related to the hemodialysis treatment. Breaking up sedentary time during hemodialysis using intradialytic exercise programs has been shown to have numerous benefits.³⁰ While these strategies are useful for dialysis days, they do not directly address sedentary behavior occurring on nondialysis days. Interventions focused on reducing sedentary behavior in the home environment may provide additional benefit due to the large amount of time this population spends at home. A recent randomized controlled trial showed that a home-based walking exercise program was able to significantly increase physical performance in dialysis patients at 6 months compared with normal daily activity.³¹ Home-based programs such as this should be seen as complimentary to intradialytic therapies and would help to interrupt sedentary behavior at home, given the amount of time per day spent in this location irrespective of dialysis or nondialysis day.

This study has a number of strengths. First, using accelerometers allowed us to objectively capture descriptive details of physical activity and sedentary behavior including intensity and duration. We chose an MET/count-based definition of sedentary behavior which more accurately describes sedentary behavior compared with steps/day. Finally, using GPS to describe locations of moderate to vigorous physical activity, light physical activity, and sedentary behavior in the hemodialysis population has not previously been done to our knowledge. Limitations of our study include a small sample size from a single center, and a cross-sectional design that does not allow participants to be followed over time. Our study highlights the difficulty with recruiting and engaging the hemodialysis population as less than half of eligible patients provided consent. A control group was not included

as our study was cross-sectional; however, physical activity in the general population has been well described. Participants may have increased their activity while wearing the accelerometer, but it is unlikely this contributed in a meaningful fashion and would have led to an underestimate of an already substantial sedentary time. Finally, activity levels may have been underestimated as devices were not worn for all awake hours, the hip-based accelerometer location may not capture stationary exercise (eg, cycling), and devices were removed before water-based activity as they were not waterproof.

Conclusion

Ambulatory, in-center hemodialysis patients demonstrate minimal moderate to vigorous physical activity and significant sedentary behavior across a limited range of locations. Given the substantial sedentary tendencies of this population, focus should be directed on increasing physical activity at any location frequented. Home-based exercise programs may serve as a potential adjunct to intradialytic-based therapies given the amount of time spent in the home environment.

Ethics Approval and Consent to Participate

The Nova Scotia Health Authority Research Ethics Board (#1022204) approved this study. All participants provided written informed consent.

Consent for Publication

All authors have provided consent for publication.

Availability of Data and Materials

Data and materials are available upon request by contacting the corresponding author Dr. Karthik Tennankore.

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Supplemental Material

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