Renal Replacement Therapy

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Effect of walkability on the physical activity of hemodialysis patients: a multicenter study

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Abstract

Introduction Physical activity is an important prognostic factor in patients undergoing hemodialysis. Walkability also affects physical activity. This study aimed to examine the effects of walkability on the physical activity of patients undergoing hemodialysis.

Methods This multicenter study included 372 outpatients (69.1 ± 11.9 years, 229 males) undergoing hemodialysis at eight facilities in Japan. Patients were classified into two groups according to the walk score (WS) at home: WS ≥ 50 (walkable area group) and WS < 50 (car-dependent area group). The effects of WS on total physical activity, moderate-to-vigorous physical activity (MVPA), and walking that was assessed using the International Physical Activity Questionnaire (IPAQ) were examined.

Results In the multivariate analysis, WS ≥ 50 was positively associated with walking ($\beta = 0.129$, $p = 0.013$) and negatively associated with MVPA ($\beta = -0.102$, $p = 0.045$). Subgroup analysis stratified by the age of 65 years showed similar results in both groups.

Conclusions Walkability is associated with various intensities of physical activity in Japanese patients undergoing hemodialysis. Exercise management should take into account the characteristics of physical activity, depending on the residential area.

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Keywords Hemodialysis, Multicenter study, Physical activity, Walkability, Walk score

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Background

Physical activity affects the prognosis of patients undergoing hemodialysis. Inactive patients undergoing hemodialysis have higher mortality rates and a 22% reduction in mortality risk per 10 min/day of physical activity [1, 2]. In addition, patients undergoing hemodialysis have time constraints due to their 4-h dialysis treatments and post-dialysis fatigue, which create barriers to increasing their physical activity levels. Therefore, compared with the healthy population, patients undergoing hemodialysis are inactive [3]. In contrast, a recent systematic review showed that intradialytic exercise improves physical function and quality of life [4]. Intradialytic exercise has the advantage of converting the bed rest time associated with dialysis treatment into physical activity. Thus, physical activity plays an important role in the management of patients undergoing hemodialysis.

Walkability is an indicator of sidewalk availability in a neighborhood environment, which affects physical activity [5]. In walkable areas, leisure activities, such as walking, and daily activities, including commuting to work and shopping, are promoted. A previous study showed that older adults living in walkable areas had higher levels of physical activity [6]. Furthermore, older people living in walkable areas showed less decline in physical activity associated with aging [7]. Therefore, walkability and physical activity may be positively correlated. However, because these studies were based on healthy populations, the relationship among patients with chronic diseases remains unknown.

Walk score (WS) is an indicator of walkability. WS can quantify the walkability of any location and can be easily calculated free of charge from a website [8]. WS are normalized and range from 0 to 100. Higher scores indicate higher walkability. WS has been shown to be reliable and valid [9, 10]. In Japan, WS is used in community populations and patients who had a stroke; however, no studies using WS in patients undergoing hemodialysis have been reported [11, 12]. In the USA, WS and number of steps have been reported to be positively correlated in patients undergoing hemodialysis [13]. However, the relationship between walkability and intensity of physical activity is unclear. The influence of confounding factors, such as physical function, job status, and activities of daily living (ADL), is unclear. Therefore, the effect of walkability on physical activity in patients undergoing hemodialysis remains unclear.

This study aimed to examine the relationship between walkability and intensity of physical activity in Japanese patients undergoing hemodialysis.

Methods

Participants and setting

This cross-sectional study included patients undergoing hemodialysis at eight Japanese facilities between January 2021 and February 2022. The inclusion criteria were patients undergoing outpatient hemodialysis who consented to participate in the study. Patients who died during the study period were not included. The exclusion criterion was patients with missing data. This study was approved by the ethics committee of the institution where it was conducted (approval number: 2020-2-001) and was registered at the University Hospital Medical Information Network Center (UMIN000050089). Written informed consent was obtained from all the participants.

Clinical characteristics

The clinical characteristics of the participants were collected from medical records and included age, sex, body mass index (BMI), primary disease at dialysis induction, time on dialysis, comorbidities, family members living with the patient, and job status. Blood laboratory data were tested for hemoglobin, albumin, and C-reactive protein levels. The Geriatric Nutritional Risk Index (GNRI) was used to measure the nutritional status [14]. This was calculated using the following formula using albumin levels and body weight: GNRI = [14.89 × serum albumin level (g/dL)] + [41.7 × (current weight/ideal weight)]. The ideal body weight was measured using a BMI of 22 kg/m^2. Physical function was assessed using grip strength and a short physical performance battery (SPPB) [15]. Grip strength was measured bilaterally using a hand dynamometer, and the maximum value was used. SPPB is a performance test consisting of standing balance, walking, and standing movements. Each task was rated on a scale of 0–4, and the total score was calculated. Higher scores indicated higher physical function. ADL was assessed using the Barthel index [16], and frailty was assessed by using the Japanese version of the revised Cardiovascular Health Study criteria [17]. This means that, if three or more of the following five criteria were applicable, the patient had frailty: “weight loss,” “muscle weakness,” “fatigue,” “slow walking speed,” and “low physical activity.” Physical therapists performed all evaluations.

Neighborhood walkability index

The WS was used to assess neighborhood walking attributes. The WS for participant’s residences were calculated using the website, https://www.walkscore.com/. Based on a previous study, WS < 50 was considered a “car-dependent area,” and WS ≥ 50 was considered a "walkable area" [18]. In the case that the participant's address was not covered by the website, it was treated as missing data.

Physical activity

Physical activity was assessed once using the International Physical Activity Questionnaire (IPAQ) [19]. The IPAQ is a questionnaire that assesses the number of days spent walking or performing moderate-to-vigorous physical activity (MVPA) per week. The following formula was used to calculate: vigorous physical activity (MET × min/week) = 8.0 METs × vigorous physical activity time per day (min × day) × number of days of vigorous physical activity per week (day/week); moderate physical activity (MET × min/week) = 4.0 METs × moderate physical activity time per day (min × day) × number of days of moderate physical activity per week (day/week); and walking physical activity (MET × min/week) = 3.3 METs × walking physical activity time per day (min × day) × number of days of walking physical activity per week (day/week). The original version of the IPAQ uses English. The Japanese version was used in this study. This Japanese version of the IPAQ has been shown to be valid, while not fully reliable, in the older population in Japan [20].

The IPAQ was developed for adults and has proven reliability and validity [19]. In older adults, validity is high, but reliability is low [21]. In Chinese patients undergoing hemodialysis, the IPAQ has demonstrated reliability, but the female sex and age should be taken into account when interpreting the results [22]. Although the IPAQ has not been shown to be reliable or valid in Japanese patients undergoing hemodialysis, it is a simple and useful tool. Previous studies have used this tool to assess physical activity in Japanese outpatients undergoing hemodialysis [23, 24]. Total physical activity was calculated by adding walking and MVPA (MET × min/week).

Statistical analysis

Continuous data are presented as mean (standard deviation) or median [25–75% percentile]. Categorical data are presented as the number (%) of individuals.

The comparison of the car-dependent and walkable areas was performed using the Mann–Whitney U and chi-squared tests. Multivariate analysis was performed with the IPAQ as the dependent variable and walkable area (dummy variable conversion: 1 = walkable area, 0 = car-dependent area) as the independent variable adjusted for age, sex, BMI, job (dummy variable conversion: employed = 1, unemployed = 0), SPPB, Barthel Index, time on dialysis, and comorbidities (diabetes, ischemic heart disease, peripheral arterial disease, cerebrovascular disease, and fracture). The IPAQ was used to analyze total physical activity, walking, and MVPA. As a subgroup analysis, a multivariate analysis was performed with IPAQ as the dependent variable and walkable area as the independent variable, according to age (≥ 65 years or < 65 years). Physical activity between farmers and non-farmers in car-dependent areas was compared using the Mann–Whitney U test. Spearman's rank correlation coefficient was used to examine the relationship between walkability and total physical activity.

All statistical analyses were performed using SPSS version 28.0 (IBM Corp., Armonk, NY, USA). Statistical significance was set at $p < 0.05$.

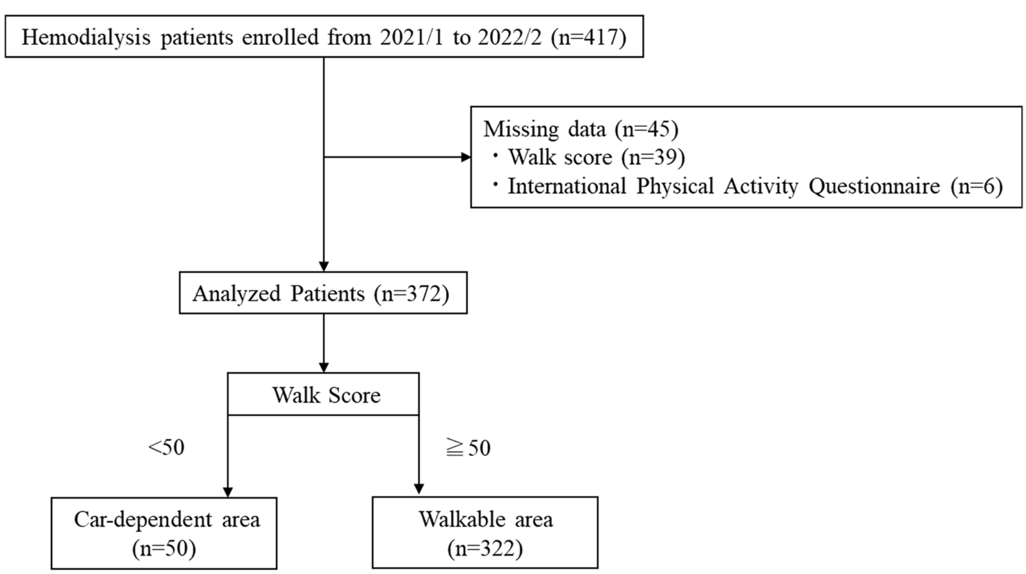

Fig. 1 Flowchart of the study

Results

Figure 1 presents the flowchart of the study. Of 372 patients included in this analysis, 50 lived in areas that were classified as car-dependent and 322 as walkable.

Table 1 shows the comparison of patient characteristics between the two groups. The mean age was 69.1 ± 11.9 years, and 229 (61.6%) were men. A total of 262 patients aged ≥ 65 years underwent hemodialysis. There were no significant differences in terms of age, sex, or dialysis duration between the two groups. In the car-dependent areas, there were significantly fewer people living alone ($p = 0.014$) and a higher proportion of farmers ($p < 0.001$). There were no significant differences in terms of physical function or the Barthel Index and the number of frail patients. The total physical activity (including walking activity) on the IPAQ was not significantly different between the two groups, but walking was higher in the walkable area ($p = 0.003$),

Table 1 Patient characteristics between the two groups

	Total	Car-dependent area	Walkable area	p value		Total	Car-dependent area	Walkable area	p value
	n = 372	n = 50	n = 322			n = 372	n = 50	n = 322	
Age (years)	69.1 (11.9)	69.6 (12.3)	69.0 (11.8)	0.645	Working (n, %)	83 (22.3)	16 (32.0)	67 (20.8)	0.077
Sex (men; women)	229; 143	31; 19	198; 124	0.945	Farmer (n, %)	15 (4.0)	7 (14.0)	8 (2.5)	< 0.001
BMI (kg/m^2)	22.6 (4.5)	22.7 (4.4)	22.6 (4.5)	0.881	Blood laboratory data				
Primary disease (n, %)					Hemoglobin (g/dl)	11.1 (5.0)	11.0 (1.3)	11.1 (5.3)	0.153
Diabetic nephropathy	139 (37.4)	18 (36.0)	121 (37.6)	0.830	Albumin (g/dl)	3.5 (0.4)	3.5 (0.4)	3.5 (0.4)	0.453
Nephrosclerosis	63 (16.9)	14 (28.0)	49 (15.2)	0.025	C-reactive protein (mg/dl)	0.5 (1.5)	1.0 (2.3)	0.4 (1.3)	0.164
Chronic glomerulonephritis	67 (18.0)	8 (16.0)	59 (18.3)	0.691	GNRI	95.1 (10.7)	94.7 (11.2)	95.2 (10.6)	0.735
IgA nephropathy	12 (3.2)	2 (4.0)	10 (3.1)	0.668	Use transportation to the hospital	160 (43.0)	19 (38.0)	141 (43.8)	0.442
Polycystic kidney disease	18 (4.8)	0 (0.0)	18 (5.6)	0.148	Walk Score	75.6 (23.4)	26.9 (16.5)	83.2 (12.8)	< 0.001
Other	47 (12.6)	7 (14.0)	40 (12.4)	0.755	Handgrip strength (kg)				
Unknown	26 (7.0)	1 (2.0)	25 (7.8)	0.228	Men	27.9 (8.2)	27.3 (8.4)	27.9 (8.2)	0.690
Time on dialysis (years)	7.3 (7.3)	7.1 (8.1)	7.4 (7.2)	0.326	Women	17.6 (5.2)	18.0 (4.9)	17.5 (5.3)	0.781
Comorbidities (n, %)					SPPB	11 [8–12]	11 [7–12]	11 [8–12]	0.351
Diabetes mellitus	172 (46.2)	24 (48.0)	148 (46.0)	0.788	Barthel Index	100 [100–100]	100 [90–100]	100 [100–100]	0.078
Ischemic heart disease	148 (39.8)	20 (40.0)	128 (39.8)	0.973	IPAQ (METs•min/week)				
Peripheral artery disease	96 (25.8)	11 (22.0)	85 (26.4)	0.509	Total	861.9 (1533.9)	890.9 (2250.0)	857.5 (1400.7)	0.821
Cerebrovascular disease	77 (20.7)	9 (18.0)	68 (21.1)	0.613	Walking activity	610.2 (1029.0)	372.6 (465.4)	646.0 (1084.8)	0.003
Fracture	69 (18.5)	6 (12.0)	63 (19.6)	0.200	MVPA	284.8 (1009.8)	571.6 (1925.3)	240.2 (773.2)	0.002
Living alone (n, %)	69 (18.5)	3 (6.0)	66 (20.5)	0.014	Frail (n, %)	137 (36.8)	14 (28.0)	123 (38.2)	0.164

Mean (SD), Median [25–75 percentile], n (%)

BMI body mass index, *SMI* Skeletal Muscle Mass Index, *SPPB* Short Physical Performance Battery, *IPAQ* International Physical Activity Questionnaire, *MVPA* moderate-to-vigorous physical activities

Table 2 Multiple regression analysis for physical activity in patients undergoing hemodialysis

	Total		Walking activity		MVPA	
	β	p	β	p	β	p
Overall						
Working	−0.225	< 0.001	−0.146	0.009	−0.163	0.004
SPPB	0.188	0.007	0.219	0.002	0.101	0.154
Barthel Index	−0.017	0.794	−0.007	0.915	−0.035	0.597
Walkable area (1)	0.007	0.892	0.129	0.013	−0.102	0.045
Non-working patients						
SPPB	0.345	< 0.001	0.280	< 0.001	0.225	0.006
Barthel Index	−0.064	0.401	−0.017	0.777	−0.119	0.143
Walkable area (1)	0.105	0.072	0.186	0.023	−0.080	0.173

Walkable area: 1, Car-dependent area: 0

MVPA moderate-to-vigorous physical activity, *SPPB* Short Physical Performance Battery

and MVPA was higher in the car-dependent area ($p = 0.002$).

Table 2 shows the results of the multivariate analysis of the IPAQ. Overall (Table 2), the walkable area was not associated with total physical activity (including walking activity), but was positively associated with walking ($\beta = 0.129$, $p = 0.013$) and negatively associated with MVPA ($\beta = -0.102$, $p = 0.045$). Among non-working patients (Table 2), the walkable area was not associated with total physical activity and MVPA, but was positively associated with walking ($\beta = 0.186$, $p = 0.023$).

The first part of Table 3 shows the results of the multivariate analysis of the subgroups based on age. In both subgroups, the walkable area was not associated with total physical activity but was positively associated with walking (≧ 65 years: $\beta = 0.125$, $p = 0.048$; < 65 years: $\beta = 0.208$, $p = 0.044$) and negatively associated with MVPA (≧ 65 years: $\beta = -0.101$, $p = 0.047$; < 65 years: $\beta = -0.199$, $p = 0.033$). The second part of Table 3 shows the results of the multivariate analysis based on age in non-working patients. Among non-working patients, living in walkable area was associated with walking activity regardless of age (≧ 65 years: $\beta = 0.161$, $p = 0.046$; < 65 years: $\beta = 0.195$, $p = 0.031$). Among non-working patients under 65 years, living in walkable areas was associated with MVPA ($\beta = -0.268$, $p = 0.047$), but not among those over 65 years.

Table 4 shows the comparison of physical activity between farmers and non-farmers in car-dependent areas. Farmers were significantly higher than non-farmers in total physical activity ($p = 0.011$), walking ($p = 0.018$), and MVPA ($p = 0.008$). After dividing the MVPA into each component, both moderate ($p = 0.018$)

Table 3 Multiple regression analysis for physical activity in patients over/under 65 years of age

	Over 65 years of age						Under 65 years of age					
	Total		Walking activity		MVPA		Total		Walking activity		MVPA	
	β	p	β	p	β	p	β	p	β	p	β	p
Overall												
Working	−0.249	< 0.001	−0.139	0.039	−0.252	< 0.001	−0.227	0.119	−0.111	0.350	−0.138	0.147
SPPB	0.173	0.053	0.184	0.042	0.071	0.256	0.268	0.014	0.289	0.010	0.170	0.113
Barthel Index	0.050	0.558	0.045	0.602	−0.022	0.731	−0.174	0.120	−0.157	0.172	−0.127	0.255
Walkable area (1)	0.069	0.268	0.125	0.048	−0.101	0.047	0.054	0.567	0.208	0.044	−0.199	0.033
Non-working patients												
SPPB	0.353	< 0.001	0.270	0.005	0.239	0.013	0.412	0.010	0.474	0.004	0.162	0.315
Barthel Index	−0.014	0.878	0.020	0.828	−0.131	0.162	−0.272	0.106	−0.287	0.092	−0.149	0.388
Walkable area (1)	0.043	0.512	0.161	0.046	0.019	0.783	0.095	0.453	0.195	0.031	-0.268	0.047

Walkable area: 1, car-dependent area: 0

MVPA moderate-to-vigorous physical activity, *SPPB* Short Physical Performance Battery

Table 4 Comparison of farmers and non-farmers in car-dependent area

	Farmers *n* = 7	Non-farmers *n* = 43	*p*-value
IPAQ (METs × min/week)			
Total	1223.9 (737.9)	460.7 (583.7)	0.011
Walking activity	561.0 (427.7)	289.6 (341.4)	0.018
MVPA	662.9 (556.1)	261.4 (735.9)	0.008
- Moderate	582.9 (605.7)	200.5 (678.7)	0.018
- Vigorous	80.0 (113.1)	61.5 (388.9)	0.020

Mean (SD)

IPAQ International Physical Activity Questionnaire,

MVPA moderate-to-vigorous physical activities

and vigorous ($p=0.020$) intensities were significantly higher for farmers than for non-farmers.

Additional file 1: (Fig. S1) shows the correlation between walkability and total physical activity. No significant association was found between WS and total physical activity ($p=0.166$).

Discussion

In this study, walkability was not associated with frailty or physical function. Frailty is associated with lower perceived neighborhood walkability among community-dwelling older adults [30]. Physical function of the older adults is also associated with neighborhood walkability [31]. It is unclear why walkability was not associated with frailty or physical function in the population of this study. Factors specific to hemodialysis, such as lower physical activity than healthy adults [3] and time constraints associated with hemodialysis, may have an impact. In addition, this study defined frailty based on physical function, whereas a previous study [30] defined frailty in a broad sense based on the Kaigo–Yobo Checklist. Frailty includes not only physical but also cognitive, psychological, social, and environmental factors [32]. Therefore, the broad sense of frailty in the previous study may differ from the emphasis on physical frailty in this study. Walkability may be associated with diverse components of frailty. The relationship of walkability to frailty and physical function needs to be clarified by further studies.

This study has several limitations. First, physical activity was assessed using IPAQ. IPAQ is less reliable in the older adults, and repeatability is also concerned[22]. There is a possibility that hemodialysis patients may perceive the definition and intensity of physical activity differently from the healthy, young population. Interpretation of results for hemodialysis patients should take into account female sex and age bias [22]. Second, the season in which the assessment was conducted differed among facilities. This assessment should be conducted simultaneously to consider seasonal changes in physical activity. Third, in this study, farmers were not defined as "full-time farmers," so it is possible that "part-time farmers" were included. In the case of part-time farmers, non-agricultural work also affects the results and should be interpreted with caution. Fourth, information about hemodialysis, such as hypotension associated with hemodialysis and hemodialysis efficiency, was not collected. This information might have affected physical activity. Fifth, the investigation of factors related to physical activity was limited. It is necessary to investigate comprehensively, including work, family caregiving, and frequency of outings. Finally, detailed MVPA activities were not evaluated. Clarifying the elements of MVPA may provide useful information for patient guidance.

The multicenter data in this study show a higher prevalence of ischemic heart disease than contemporary similar cohorts [33, 34]. This trend does not reflect specific regional characteristics, as this study included a variety of urban and rural areas in Japan. This cohort is physical-therapist-led, and physical function is the main outcome (https://center6.umin.ac.jp/cgi-open-bin/ctr/ctr_view.cgi?recptno=R000057060). In general, disease management interventions involving exercise and physical activity, such as cardiac rehabilitation [35], are more intensively implemented in cases of ischemic heart disease. Therefore, it is likely that they were more positively involved in studies that focused on physical function, such as this cohort. This may be one of the reasons for the higher prevalence of ischemic heart disease than in the physician-led, all-enrollment cohort. However, physical performance was high despite the high prevalence of complications. Because there was no information on the duration and severity of complications in this study, these should be collected in future studies. Generalization of results should be cautioned.

Conclusions

In conclusion, walkability is associated with varying intensities of physical activity in Japanese patients undergoing hemodialysis. Exercise management that takes into account the characteristics of physical activity depending on the residential area should be considered.

Abbreviations

WS	Walk score
ADL	Activities of daily living
BMI	Body mass index
GNRI	Geriatric Nutritional Risk Index
SPPB	Short Physical Performance Battery
IPAQ	International Physical Activity Questionnaire
MVPA	Moderate-to-vigorous physical activity

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s41100-024-00532-4.

Additional file 1: The correlation between walk score and total physical activity. Note: *IPAQ* International Physical Activity Questionnaire

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Author contributions
Research idea and study design were contributed by Y.S and N.U; data acquisition was contributed by Y.S, D.O, Y.K, S.K, N.S, Y.S, N.S, K.M, and Y.Y; data analysis/interpretation were contributed by Y.S, N.U, and M.S; statistical analysis was contributed by Y.S; and supervision or mentorship was contributed by N.U, Y.A, and M.S. Each author contributed important intellectual content during manuscript drafting and revision and agreed to be personally accountable for the individual's contributions, and to ensure questions about the accuracy or integrity of any portion of the work, even one in which the author was not directly involved, are appropriately investigated and resolved. All authors read and approved the final manuscript.

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Availability of data and materials
The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
This study was approved by the Ethics Committee of the Uonuma Kikan hospital where it was conducted (approval number: 2020–2-001). Written informed consent was obtained from all the participants.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

Registration
Name of the registry: A multicentre prospective cohort study on the effect of exercise and physical activity on functional decline, cardiovascular disease and mortality in patients undergoing hemodialysis. Trial registration number: R000057060. Date of registration: 2023/01/20. URL of trial registry record: Trial registration: UMIN, UMIN000050089. Registered 2023/01/20, https://center6.umin.ac.jp/cgi-open-bin/ctr/ctr_view.cgi?recptno=R000057060.

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