Yabe et al. Renal Replacement Therapy (2023) 9:40
https://doi.org/10.1186/s41100-023-00493-0

Renal Replacement Therapy

RESEARCH Open Access

Factors associated with 10-m walking speed in outpatients undergoing hemodialysis: a multicenter cross-sectional study

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Abstract

Introduction Walking ability is an important prognostic factor for patients undergoing maintenance hemodialysis (HD). Since complications such as poor nutrition, anemia, malnutrition, and inflammation in patients undergoing HD may affect walking ability, the factors affected by 10-m walking speed must be investigated. This cross-sectional study enrolled 1205 outpatients undergoing HD and measured their 10-m walking speed.

Methods Lower extremity muscle strength (LES), grip strength, one-leg standing time (OLST), and short physical performance battery (SPPB) score were measured as physical functions. Age, sex, body mass index, dialysis history, comorbidities, and hematological data were collected.

Results A multiple regression analysis revealed that the 10-m walking speed was significantly associated with LES, grip strength, OLST, SPPB, and % creatinine production rate, even after adjusting for corresponding variables ($R^2 = 0.69$, $p < 0.05$).

Conclusion Muscle strength and muscle mass may be essential factors for the 10-m walking speed in patients undergoing HD.

Keywords 10-m walking speed, Hemodialysis, Muscle strength, Muscle mass

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Introduction

The age of patients undergoing hemodialysis is increasing, and according to a statistical survey by the Japanese Society of Dialysis Medicine in 2017, the average age of patients undergoing hemodialysis (HD) is 68.43 years [1]. Patients undergoing HD are also susceptible to frailty [2] due to increased levels of bioactive substances, low nutrition, endocrine abnormalities, and uremic symptoms caused directly by chronic kidney disease, leading to impaired skeletal muscle function and decreased endurance [3, 4]. Previous studies have shown that decreased walking speed in patients undergoing HD is significantly associated with all-cause mortality [5, 6], hospitalization [6], and cardiovascular disease [7]. Moreover, older patients undergoing HD have difficulties in activities of daily living (ADL) compared to community-dwelling older adults not on HD [8], and a decrease in walking ability may be associated with low performance in ADL in the aforementioned population. Evaluating and ameliorating the ability to walk is essential for maintaining ADLs and improving the prognosis of patients undergoing HD.

The 10-m walking speed is a widely used assessment for walking ability in clinical settings. Elucidating the factors that affect 10-m walking ability is considered important for planning care to improve walking ability. Studies on healthy subjects have shown that factors affecting the 10-m walking speed were lower limb muscle strength, balance ability [9], shortening of stride length, and a decrease in walking rate [10]. In a study on patients undergoing HD, cardiac disease, history of fracture, decreased leg strength, and poor standing balance were independently associated with slow walking speed [11]. However, the factors affecting the 10-m walking speed in patients on HD have not been thoroughly investigated and must be elucidated to appropriately intervene in their walking ability.

Factors associated with walking ability in patients undergoing HD need to be considered when assessing the pathophysiology of complications, including malnutrition [12], anemia [13], and inflammation [14], which may influence the decline in physical function. Anemia associated with impaired renal function has been reported to decrease exercise tolerance due to the decreased production of erythropoietin and red blood cells [13]. Furthermore, malnutrition in patients undergoing HD is characterized by decreased food intake due to gastrointestinal disorders and chronic inflammation due to the influence of inflammatory cytokines, including interleukin-6 and tumor necrosis factor [15]. To properly manage the walking ability of patients undergoing HD, the pathophysiology associated with HD should be considered, and factors affecting walking should be investigated. Identifying factors associated with walking ability may help manage patients undergoing HD in order to maintain their walking ability; however, this has not been thoroughly investigated.

This multicenter cross-sectional study aimed to identify the factors related to walking ability associated with HD-related pathologies and physical function in patients undergoing ambulatory HD.

Materials and methods

This multicenter cross-sectional study was conducted at 22 outpatient dialysis clinics of Japan from April 2012 to April 2021. Data were retrospectively extracted from a database. The inclusion criteria were as follows: (1) Patients without ischemic heart disease, arrhythmia, or severe aortic stenosis, which are contraindications to exercise therapy as stipulated in the Clinical Practice Guideline for renal rehabilitation [16], and who are deemed by the attending physician to exhibit stability during hemodialysis treatment were included in the study, and (2) those willing to start an intradialytic exercise program. The exclusion criteria were as follows: (1) patients who could not walk independently, (2) patients who did not measure their walking speed, (3) patients who were hospitalized within the past 3 months, (4) patients with age of < 18 years, and (5) patients who underwent HD for less than 6 months. This study was approved by the Ethics Committee (approval number: 18004_01SJ). Patients' rights to avoid enrollment was pledged in an opt-out fashion.

Measurements

Patient background and blood data were collected from the medical records. Physical function was measured at the beginning of participation in the intradialytic exercise program. Grip strength, 10-m walking speed, knee extensor strength, and one-leg standing time were measured.

Age, sex, body mass index (BMI), HD vintage, Hypertension (HT), Diabetes mellitus (DM), and Dyslipidemia (DL), and hematological data were investigated. Hematological data including serum albumin (Alb), blood urea nitrogen (BUN), serum creatinine (Cr), serum phosphorus (P), serum calcium (Ca), intact parathyroid hormone (PTH-INT), hemoglobin (Hb), total iron-binding capacity (TIBC), ferritin, C-Reactive Protein (CRP), geriatric nutritional risk index (GNRI), % creatinine production rate (%CGR), standardized protein catabolic rate (nPCR), and standardized dialysis volume (Kt/V) were retrieved from the medical records. The formulas for calculating GNRI, %CGR, nPCR, and Kt/V were calculated as follows:

$$\begin{aligned}\mathrm{GNRI} &= \{14.89 \times \text{serum albumin}\ (\mathrm{g/dl})\} \\ &\quad + \{41.7 \times (\text{body weight/ideal body weight}*)\}\end{aligned}$$

$$*\text{Ideal weight (male)} = \text{height (cm)} - 100\left[(\text{height}) - 150)/4\right]$$

$$*\text{Ideal weight (female)} = \text{height (cm)} - 100\left[(\text{height}) - 150)/2.5\right]$$

$$\begin{aligned}\%\mathrm{CGR} &= \mathrm{Cs} \times [7056 \div A + \Delta\mathrm{BW} \\ &\quad \div \mathrm{IBW} \times 240 \div (72 - \mathrm{T}d)]\end{aligned}$$

$$\begin{aligned}A &= 3354 + (7.8 \times \mathrm{Td} + 411) \times \ln(\mathrm{Cr} \div \mathrm{Cs}) - 1.5 \\ &\quad \times \mathrm{Td} - 1449 \div [(0.019 \times \mathrm{Td} + 0.999) \\ &\quad \times \ln(\mathrm{Ce} \div \mathrm{Cs})]\end{aligned}$$

$$\mathrm{Cr} = [-81.622 \times \ln(\mathrm{Ce} \div \mathrm{Cs}) \div 60 \times \mathrm{Td} + 0.943] \times \mathrm{Ce}$$

Cs: Cre concentration at predialysis (mg/dL); Ce: Cre concentration at post-dialysis (mg/dL); Td: HD duration time (hours); ΔBW: Change in body weight between pre- and post-dialysis (kg)

$$\text{IBW (male):Height (cm)} - 100 - [(\text{height}) - 150]/4$$

$$\text{IBW (female):Height (cm)} - 100 - [(\text{height}) - 150]/2.5$$

If DW was more than the ideal body weight, the value of DW = IBW was calculated as 1.

$$\text{nPCR} = C_0/(a + bKt/V + c[Kt/V]) + 0.0168$$

C_0: Predialysis BUN (mg/dL); Kt/V: Single-pool estimate of the dialysis dose.

The corresponding coefficients for a, b, and c were adjusted for differences in the interdialytic time interval for patients who received dialysis three times weekly.

Kt/V was used as an index of dialysis volume and was calculated using the method [17] used in the Japanese Society for Dialysis Therapy statistical survey.

$$Kt/V = -\ln(R - 0.008 \times t) + (4 - 3.5 \times R) \times (UF/W)$$
$$R = Ct/Co$$

Ct: Postdialysis BUN (mg/dL); Co: C_0: Predialysis BUN (mg/dL); t: The duration of HD session (hour); UF: Ultrafiltration volume (kg); W: The body weight after the HD session.

The 10-m walking speed was measured at a comfortable pace along a 14-m straight walking path, including a 2-m front and rear runway, and the time required for patients to walk 10 m was measured with a stopwatch [18]. Grip strength was measured using a grip strength meter (Grip D Digital Grip Strength Meter, Takei) according to a previous study [19] in the upright standing posture. Lower extremity muscle strength (LES) was assessed using a manual muscle tester (μTasF-1, Anima) with the patient seated on a chair and their knees flexed at a 90° angle. The manual muscle tester pad was placed perpendicularly to the leg, just above the ankle. Isokinetic knee extensor strength was measured twice on each side, and the highest values for both the right and left legs were selected as the measured values [20]. The value divided by body weight was subsequently used as the knee extensor muscle strength. In one-leg standing time (OLST), a measurer stated the following instructions to the patients: "stand with one eye open, your hands on your hips, and one leg raised 5 cm from the floor for as long as possible," and one or two practice tests were conducted. The actual test was conducted using the same instructions. The time until the subject was about to fall was measured [21]. Short physical performance battery (SPPB) comprised a test of walking ability based on the 4-m walking speed, balance function based on tandem standing time, and lower limb muscle strength based on five chair standing times. SPPB reflects composite physical function and is scored on a range of 0–12 points [21]. All physical functions were measured before the HD session.

Statistical analysis

The missing components of the variables were complemented using multiple assignment methods based on the missing-at-random assumption to minimize missing bias via IBM SPSS Missing Values 28 (IBM corp.; Armonk, NY, United States). Pearson's correlation coefficient and multiple regression analysis were used to analyze the relationship between the 10-m walking speed and each variable. In a multiple regression analysis, the dependent variable was the 10-m walking speed, and explanatory variables were selected as follows: knee extensor strength and grip strength as muscle strength; one-leg standing time as balance function; SPPB as an index of full body and complex physical function; %CGR as an index of muscle mass; GNRI and nPCR as indices of nutritional status; Hb as an index of anemia; and CRP as an index of inflammation. The forced entry method was used for variable selection. Potential confounders were adjusted for age, BMI, sex, DM, HT, DL, and HD vintage (model 1). Model 2 was adjusted for Alb, BUN, Cr, P, Ca, PTH-INT, TIBC, ferritin, and KT/V, in addition to the variables of model 1. Dummy variables (0 and 1) were used for the categorical data. The coefficient of determination and standardized partial regression coefficients are shown as R^2 and β, respectively. Results of multiple regression analysis were listed with standardized β values, 95% confidence intervals for unstandardized β, and adjusted R^2. The variance inflation factor (VIF) was used to check for collinearity. A VIF of < 10 reflected a lack of collinearity and was selected as an explanatory variable. Statistical analysis was performed using IBM SPSS version 28 (IBM corp.; Armonk, NY, United States). A p-value < 0.05 was considered statistically significant.

Results

A total of 1276 outpatients undergoing HD participated in the intradialytic exercise program; 71 patients were excluded because they were unable to walk or lacked data on their 10-m walking speed. The final analysis included 1205 patients (mean age, 69.8 ± 11 years; Fig. 1). The baseline characteristics of the study participants are shown in Table 1. Figure 2 shows a histogram of the 10-m walking speed of patients. The average 10-m walk speed was 1.3 ± 0.4 m/s, and the mode value ranged from 1.4 to 1.6 m/s.

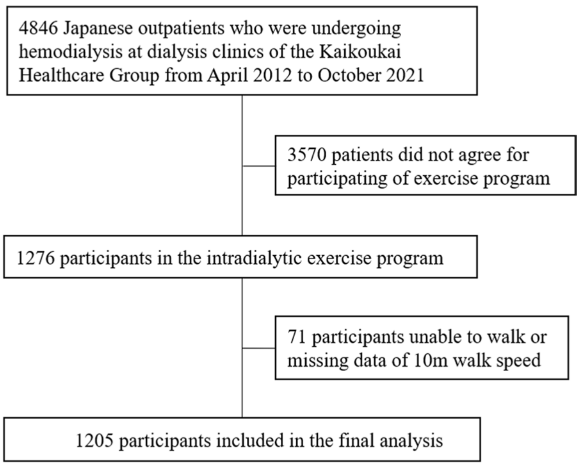

Fig. 1 Flow of participants

Table 2 shows the relationship between the 10-m walking speed and each measurement value in a single correlation and multiple regression analysis. Moreover, the 10-m walking speed significantly correlated with grip strength ($r=0.51$), LES ($r=0.6$), OLST ($r=0.44$), SPPB ($r=0.74$), % CGR ($r=0.27$), nPCR ($r=0.21$), GNRI ($r=0.15$), and CRP ($r=-0.11$) ($p<0.05$). Results of the multiple regression analysis showed that grip strength ($\beta=0.19$, 0.19), LES ($\beta=0.19$, 0.19), OLST ($\beta=0.07$, 0.07), SPPB ($\beta=0.5$, 0.5), and %CGR ($\beta=0.11$, 1) had a significant relationship with 10-m walking speed after adjustment for some confounding factors ($R^2=0.69$ and 0.69 for models 1 and 2, respectively; $p<0.05$). The variables of all items had a VIF of < 10, and there was no multicollinearity. The sensitivity analysis results are presented in supplement tables without substituting missing values and without including the SPPB variable in the multiple regression analysis (Additional file 1: Supplemental Tables 1 and 2). The finding did not show a significant change.

Discussion

To our knowledge, this study is the first to show the factors associated with the 10-m walking speed in patients undergoing HD. The multicenter, large cross-sectional data of this study revealed that muscle strength, muscle mass, and balance ability, but not anemia, inflammation, and nutrition were significantly associated with the 10-m walking speed. Since anemia, malnutrition, and inflammation are common complications in most patients undergoing dialysis, the results of this study showed that the 10-m walking speed is an independent indicator of physical function and provides valid evidence for the assessment and interventions of walking ability in patients undergoing HD.

Table 1 Patient characteristics

	n **= 1205**
Participant background data	
Age (years)	69.8 ± 11
Sex (male/female)	687/518
BMI (kg/m^2)	21.9 ± 4.2
Dialysis vintage (month)	78.3 ± 96.2
Cause of dialysis (n, %)	
Diabetic nephropathy	411 (34.1)
Chronic glomerulonephritis	234 (19.4)
Nephrosclerosis	176 (14.6)
Polycystic kidney disease	38 (3.2)
Chronic pyelonephritis	5 (0.4)
RPGN	10 (0.8)
Other	73 (6.1)
Unknown	258 (21.4)
Comorbidities (n, %)	
Hypertension	728 (60.4)
Diabetes	531 (44.6)
Dyslipidemia	228 (18.9)
Hematological data	
Alb (g/dL)	3.5 ± 0.4
BUN (mg/dL)	58.2 ± 14.8
Cr (mg/dL)	9.6 ± 2.6
P (mg/dL)	5.2 ± 1.2
Ca (mg/dL)	8.6 ± 0.8
PTH-INT (pg/mL)	168.5 ± 147.9
Hb (g/dL)	11 ± 1.4
TIBC (μg/dL)	244.6 ± 62.2
Ferritin (ng/mL)	99.2 ± 104.8
CRP (g/dL)	0.4 ± 0.7
GNRI	92.1 ± 8.2
% CGR (%)	95.3 ± 29.3
nPCR (g/kg/day)	0.8 ± 0.2
Kt/V	1.6 ± 0.3
Physical function	
10-m walking speed (m/s)	1.3 ± 0.4
Grip strength (kg)	22.1 ± 7.9
LES (%)	40.4 ± 14.9
OLST (s)	16.2 ± 29.2
SPPB (point)	9.6 ± 2.7

Values are expressed as mean ± SD or numbers (%)

BMI body mass index, *RPGN* rapidly progressive glomerulonephritis, *Alb* albumin, *BUN* blood urea nitrogen, *Cr* creatinine, *P* phosphorus, *Ca* calcium, *PTH-INT* intact-parathyroid hormone, *Hb* hemoglobin, *CRP* C-reactive protein, *GNRI* geriatric nutrition risk index, *%CGR* creatinine generation rate, *nPCR* normalized protein catabolism rate, *TIBC* total iron-binding capacity, *LES* lower extremity muscle strength, *OLST* one-leg standing time, *SPPB* short physical performance battery

The decline in the walking ability of patients undergoing HD is an important problem. Previous studies have shown that walking speed in patients undergoing HD is

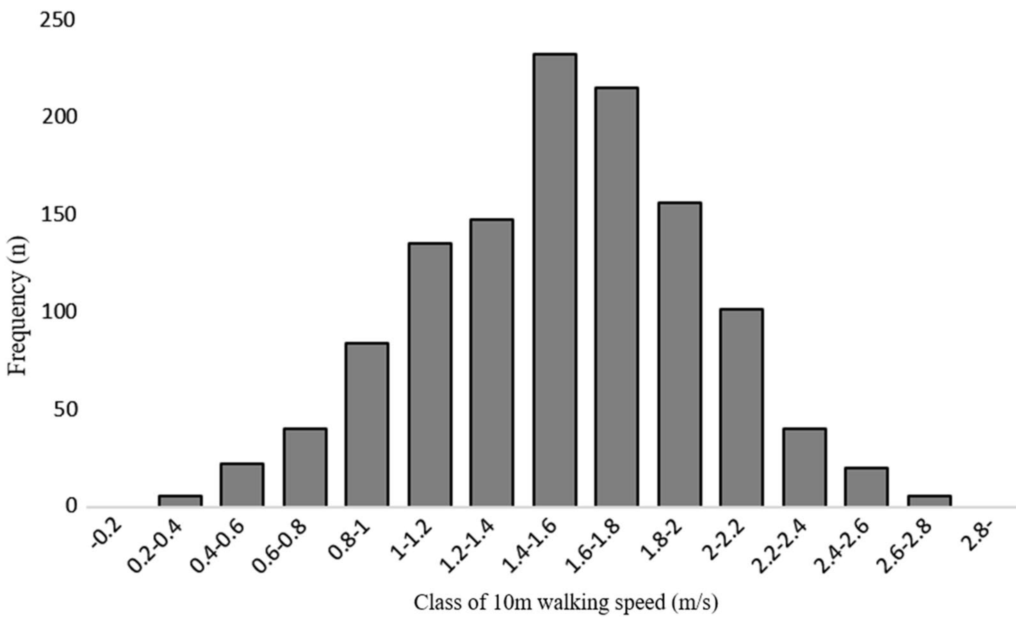

Fig. 2 Histogram of the 10-m waking speed at different frequencies

Table 2 Multiple regression analysis of the 10-m walk speed

	Univariate correlation		Multiple regression Model 1			Multiple regression Model 2			
	r	**95% CI**	***p***	***β***	**95% CI**	***p***	***β***	**95% CI**	***p***
Grip strength	0.51	0.5–0.58	< 0.01	0.19	0.008–0.013	< 0.01	0.19	0.008–0.014	< 0.01
LES	0.6	0.58–0.65	< 0.01	0.19	0.004–0.007	< 0.01	0.19	0.004–0.007	< 0.01
OLST	0.44	0.4–0.49	< 0.01	0.07	0–0.002	< 0.01	0.07	0–0.002	< 0.01
SPPB	0.74	0.74–0.78	< 0.01	0.5	0.076–0.089	< 0.01	0.5	0.076–0.09	< 0.01
%CGR	0.27	0.25–0.35	< 0.01	0.11	0.001–0.002	< 0.01	0.1	0.001–0.002	< 0.01
nPCR	0.21	0.17–0.28	< 0.01	− 0.01	− 0.124 to 0.06	0.49	− 0.06	− 0.322 to 0.001	0.06
GNRI	0.15	0.14–0.25	< 0.01	0.02	− 0.001 to 0.003	0.25	− 0.01	− 0.005 to 0.004	0.87
Hb	0.02	− 0.02 to 0.09	0.25	− 0.01	− 0.013 to 0.007	0.55	− 0.01	− 0.013 to 0.008	0.6
CRP	− 0.11	− 0.18 to − 0.07	< 0.01	− 0.01	− 0.027 to 0.014	0.53	− 0.01	− 0.027 to 0.014	0.55

Model 1: Adjusted for age, BMI, sex, DM, HT, DL, and HD vintage, $R^2 = 0.69$, $p < 0.05$

Model 2: Adjusted for age, BMI, sex, DM, and HD vintage, as well as Alb, BUN, Cr, P, Ca, KT/V, PTH-INT, TIBC, and Ferritin, $R^2 = 0.69$, $p < 0.05$

BMI body mass index, *DM* diabetes mellitus, *HT* hypertension, *DL* Dyslipidemia, *LES* lower extremity muscle strength, *OLST* one-leg standing time, *SPPB* short physical performance Battery, *% CGR* creatinine generation rate, *PCR* normalized protein catabolism rate, *GNRI* Geriatric Nutrition Risk Index, *Hb* hemoglobin, *CRP* C-reactive protein, R^2 adjusted coefficient of determination, *β* standardized partial regression coefficient, *95% CI* confidence interval, 95% confidence intervals for unstandardized *β*

significantly associated with higher mortality [5, 6] and affects quality of life more than other measures of physical function [18]. Ambulatory patients with end-stage renal disease undergoing dialysis have decreased walking speed, being 60% of that of age-matched controls [22]. Another study showed that a 10-m walking speed decline was observed without an accompanying decline in LES and SPPB over 1 year in a group of older patients undergoing HD without exercise intervention [23]. These studies suggest that a 10-m walking speed is a good indicator with high power to detect mortality and decline in physical function. Additionally, previous studies have reported that many ambulatory patients undergoing HD have difficulty with activities, walking, and passing through stairways, despite their high scores on the "mobility" item of the functional independence measure (FIM) and the fact that they do not require assistance [24, 25]. The high mobility of patients undergoing HD as assessed by FIM does not indicate that they can move without problems, but rather that a certain number of patients have difficulty moving around. Evaluation of walking ability in patients undergoing HD is important to improve life expectancy and performance of ADLs and to solve difficulties in mobility.

This study showed that walking ability is associated with muscle strength and mass in patients undergoing HD. Prior research on 10-m walking speed has explored variables such as age [26], gender [27], muscle strength [27], and balance [27]. This study introduces a novel aspect by demonstrating the significance of the %CGR as a specific metric for patients undergoing HD. A recent study showed that muscle strength declines with age [28], and a decrease in LES predicts a decrease in walking speed in older adults [9]. Additionally, because the muscle strength of patients undergoing dialysis is lower than that of age-matched healthy controls [29], the walking ability of patients undergoing dialysis may be affected by muscle strength affected by both aging and renal failure. Muscle mass is also a factor that influences walking ability. Handgrip strength is associated with the tension exerted by different muscle groups [30] and is also related to whole-body muscle mass [31] and nutritional status [32] in patients undergoing HD. %CGR also indicates muscle mass in patients undergoing HD [33], as well as reduced muscle mass due to uremic sarcopenia [34]. The results of the present study may support those of the abovementioned studies; the 10-m walking speed may be an indicator that reflects not only LES, but also the muscles of the whole body.

OLST and SPPB, which reflect balance ability and whole-body physical function, were also associated with 10-m walking speed. The acquisition of weight-bearing function in both lower limbs is a prerequisite for independent walking, and standing on one leg is a movement that requires these functions. A previous study reported that a higher OLST was associated with whether patients were able to walk independently [7]. Another study showed that in 122 outpatients on HD, the factors that independently discriminated lower walking speed were poor standing balance in addition to cardiac disease, history of fracture, and decreased leg strength after adjusting for confounders [7]. Additionally, lower SPPB scores are associated with the likelihood of falls through step length and slow-walking speed in patients with CKD [35]. A previous randomized controlled trial showed that intradialytic exercise for older patients undergoing HD affected SPPB without improvement of LES [36]. Muscle strength is an indicator of the functional factors of a single motor unit, whereas OLST and SPPB reflect whole-body neuromuscular control and functional factors. Balance capacity and SPPB are important factors of walking ability in addition to muscle strength and muscle mass.

An interesting aspect of the results of the present study is that anemia, nutritional status, and inflammation status in patients undergoing HD showed no significant association with the 10-m walking speed. A previous study showed the nutritional status [37], inflammatory status [38], and anemia [39] have been identified as determinants influencing the walking speed of community-dwelling older persons. In addition aging, prolonged dialysis period, and inflammatory status in patients undergoing HD worsen nutritional status, as well as skeletal muscle function and walking ability [12–14]. Other studies have shown that low nutritional status is associated with physical functions, including the 10-m walking speed and muscle strength [40, 41]. Furthermore, factors such as chronic inflammation and endocrine abnormalities in patients on HD are associated with sarcopenia [42]. Therefore, although nutritional status and inflammation do not directly affect the 10-m walking speed, they may indirectly affect the speed by affecting sarcopenia and skeletal muscle mass loss. One plausible explanation for the lack of association between 10 m walking speed and nutritional status, inflammation, and anemia in this study could be the absence of severely compromised GNRI, CRP, or Hb level among the included HD patients. A prior study investigating the extent of independent ambulation among individuals undergoing HD documented the impact of insufficient nutrition (GNRI < 86) [12] and inflammation (CRP decline in the walking independence group mean: 0.43, no decline in the walking independence group: 0.08 g/dL) [14]. However, within the context of the present study, the GNRI exhibited elevated values (mean 92), and the CRP levels were diminished (mean 0.4 g/dL). Therefore, no significant differences were discernible in terms of GNRI and CRP. Previous research has noted the influence of anemia on walking distance [13], but its impact on walking speed among dialysis outpatients remained uncertain. Hence, in ambulatory patients receiving HD, such as the subjects in this study, further investigation is required to determine the relationship between anemia and walking speed. The 10-m walking speed may be an index that reflects systemic factors related to whole-body motor control more than physiological and functional structural factors do. The relationships between nutritional status, inflammation, physical function, and walking ability should be investigated.

Complex interventions for LES, muscle mass, and balance capacity may be important for improving the walking ability of patients on HD. The results presented in this study suggest the importance of balance training and exercises requiring control of whole-body movements, including exercises requiring multiple neuromuscular coordination rather than a single joint movement, for improving the 10-m walking speed. Previous studies have shown that intradialytic exercise affect muscle strength, balance, and walking ability [43, 44]. Additionally, aerobic exercise and resistance training on non-dialysis days improve balance function [45]. Exercise on non-dialysis days, which does not limit the type of exercise, may be more important than that on dialysis days for improving walking ability because it allows whole-body movement. In contrast, a previous systematic review showed that exercise therapy for patients on dialysis had a poor effect on increasing the effect of skeletal muscle mass [46], which may be due to low nutrition and inflammation. Several studies have reported that a combination of nutritional and exercise therapy significantly improves physical function compared with nutritional therapy alone [47, 48]. In the future, improving walking ability may require a combination of nutritional and exercise therapies to address malnutrition and inflammation and non-dialysis interventions to provide whole-body exercise.

This study had some limitations. First, the 10-m walking speed was evaluated at a comfortable pace. This is because a comfortable walking speed was determined to be more reflective of the patient's daily activity than maximum walking speed; however, maximum walking speed may provide a more perceptive assessment of the patient's walking ability. Second, this study only included subjects who voluntarily participated in an exercise program. Although the results are from a large cohort, and the patient backgrounds are indicative of patients undergoing dialysis in general, generalizability to the overall population of dialysis patients may be limited. Third, this study exclusively examines factors associated with the 10-m walking speed and does not explore other indices of physical functionality, such as the 6-min walk test. It is important to duly acknowledge and consider factors related to additional measures of physical function in future research. The fourth limitation of this study is the inability to adequately adjust for comorbidities as a confounding factor. Specific comorbidities, including fractures and cardiac disease, may influence walking speed in patients undergoing HD. Unfortunately, due to the nature of secondary analysis and the available data, it was impossible to include information on these comorbidities as explanatory variables. Future studies should aim to adjust for comorbidities further to explore their impact on walking speed in HD patients.

This cross-sectional large data study investigated the factors associated with 10-m walking speed in outpatients undergoing ambulatory HD. Muscle strength, muscle mass, balance capacity, and whole-body physical function were extracted as factors related to the 10-m walking speed. In addition to nutritional status, inflammation and anemia were not associated with the 10-m walking speed. Improvements in strength, muscle mass, and balance capacity are important for improving the walking ability of patients undergoing dialysis.

Abbreviations

ADL	Activity Daily Living
BMI	Body mass index
Alb	Serum albumin
BUN	Blood urea nitrogen
Cr	Serum creatinine
P	Serum phosphorus
Ca	Serum calcium
PTH-INT	Intact parathyroid hormone
Hb	Hemoglobin
TIBC	Total iron-binding capacity
CRP	C-reactive protein
GNRI	Geriatric nutritional risk index
%CGR	% Creatinine production rate
nPCR	Standardized protein catabolic rate
Kt/v	Standardized dialysis volume
LES	Lower extremity muscle strength
OLST	One-leg standing time
SPPB	Short physical performance battery
VIF	Variance inflation factor
FIM	Functional independence measure

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s41100-023-00493-0.

Additional file 1. Table S1: Multiple regression analysis of the 10-m walk speed (missing values are not substituted). **Table S2**: Multiple regression analysis of the 10-m walk speed (SPPB are not substituted).

Acknowledgements

We want to thank the study participants for their cooperation. We also express our gratitude to the Department of renal dialysis staff for their cooperation during this study.

Author contributions

Research idea and study design were contributed by H.Y, H.N; data acquisition was contributed by H.Y, H.N, R.T, Y.M; data analysis/interpretation were contributed by H.Y, H.N, T.Y; statistical analysis was contributed by H.Y, H.N, T.Y; supervision or mentorship was contributed by K.K, Y.M, T.Y. Each author contributed important intellectual content during manuscript drafting and revision, 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.

Funding

Not applicable.

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

All procedures were approved by the Ethics committee of the Kaikoukai Healthcare Group (Approval Number. 18004_01SJ). Patients' rights to avoid enrollment was pledged in an opt-out fashion.

Consent for publication
Not applicable.

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

Received: 14 March 2023 Accepted: 21 July 2023
Published online: 05 August 2023

References

1. Nitta K, Masakane I, Hanafusa N, Taniguchi M, Hasegawa T, Nakai S, et al. Annual dialysis data report 2017, JSDT Renal Data Registry. Ren Replace Ther. 2019;5:53. https://doi.org/10.1186/s41100-019-0248-1.
2. Lee HJ, Son YJ. Prevalence and associated factors of frailty and mortality in patients with end-stage renal disease undergoing hemodialysis: a systematic review and meta-analysis. Int J Environ Res Public Health. 2021;18(7):3471. https://doi.org/10.3390/ijerph18073471.
3. Sutcliffe BK, Bennett PN, Fraser SF, Mohebbi M. The deterioration in physical function of hemodialysis patients. Hemodial Int. 2018;22(2):245–53.
4. Roshanravan B, Patel KV. Assessment of physical functioning in the clinical care of the patient with advanced kidney disease. Semin Dial. 2019;32(4):351–60.
5. Lee YH, Kim JS, Jung SW, Hwang HS, Moon JY, Jeong KH, et al. Gait speed and handgrip strength as predictors of all-cause mortality and cardiovascular events in hemodialysis patients. BMC Nephrol. 2020;21(1):166. https://doi.org/10.1186/s12882-020-01831-8.
6. Kutner NG, Zhang R, Huang Y, Painter P. Gait speed and mortality, hospitalization, and functional status change among hemodialysis patients: a US renal data system special study. Am J Kidney Dis. 2015;66(2):297–304.
7. Abe Y, Matsunaga A, Matsuzawa R, Yoneki K, Harada M, Watanabe T, et al. Evaluating the association between walking speed and reduced cardio-cerebrovascular events in hemodialysis patients: a 7-year cohort study. Ren Replace Ther. 2016;2:54. https://doi.org/10.1186/s41100-016-0063-x.
8. Kutsuna T, Isobe Y, Watanabe T, Matsunaga Y, Kusaka S, Kusumoto T, et al. Comparison of difficulty with activities of daily living in elderly adults undergoing hemodialysis and community-dwelling individuals: a cross-sectional study. Ren Replace Ther. 2019;5:50. https://doi.org/10.1186/s41100-019-0250-7.
9. Fragala MS, Alley DE, Shardell MD, Harris TB, McLean RR, Kiel DP, et al. Comparison of handgrip and leg extension strength in predicting slow gait speed in older adults. J Am Geriatr Soc. 2016;64(1):144–50.
10. Thomas KS, Russell DM, Van Lunen BL, Colberg SR, Morrison S. The impact of speed and time on gait dynamics. Hum Mov Sci. 2017;54:320–30.
11. Abe Y, Matsunaga A, Matsuzawa R, Kutsuna T, Yamamoto S, Yoneki K, et al. Determinants of slow walking speed in ambulatory patients undergoing maintenance hemodialysis. PLoS ONE. 2016;11:3. https://doi.org/10.1371/journal.pone.0151037.
12. Tanaka T, Nishiyama K, Yamamura O, Watase H, Yokoyama Y, Horiguchi T, et al. Geriatric Nutritional Risk Index for independent walking function in maintenance hemodialysis patients: a single-facility retrospective cohort study. Geriatr Gerontol Int. 2018;18(11):1556–61.
13. Garcia RSA, Lucinda LMF, Ramos FA, Bueno GS, de Oliveira GMR, Bonisson LS, et al. Factors associated with functional capacity in hemodialysis patients. Artif Organs. 2017;41(12):1121–6.
14. Hirano Y, Fujikura T, Kono K, Ohashi N, Yamaguchi T, Hanajima W, et al. Decline in walking independence and related factors in hospitalization for dialysis initiation: a retrospective cohort study. J Clin Med. 2022. https://doi.org/10.3390/jcm11216589.
15. Sahathevan S, Khor BH, Ng HM, Gafor AHA, Mat Daud ZA, Mafra D, et al. Understanding development of malnutrition in hemodialysis patients: a narrative review. Nutrients. 2020. https://doi.org/10.3390/nu12103147.
16. Yamagata K, Hoshino J, Sugiyama H, et al. Clinical practice guideline for renal rehabilitation: systematic reviews and recommendations of exercise therapies in patients with kidney diseases. Ren Replace Ther. 2019;5:28. https://doi.org/10.1186/s41100-019-0209-8.
17. Shinzato T, Nakai S, Fujita Y, Takai I, Morita H, Nakane K, et al. Determination of Kt/V and protein catabolic rate using pre- and postdialysis blood urea nitrogen concentrations. Nephron. 1994;67(3):280–90.
18. Cleland BT, Perez-Ortiz A, Madhavan S. Walking test procedures influence speed measurements in individuals with chronic stroke. Clin Biomech. 2020;80:66. https://doi.org/10.1016/j.clinbiomech.2020.105197.
19. Zelle DM, Klaassen G, van Adrichem E, Bakker SJ, Corpeleijn E, Navis G. Physical inactivity: a risk factor and target for intervention in renal care. Nat Rev Nephrol. 2017;13(3):152–68.
20. Hirano M, Katoh M, Gomi M, Arai S. Validity and reliability of isometric knee extension muscle strength measurements using a belt-stabilized hand-held dynamometer: a comparison with the measurement using an isokinetic dynamometer in a sitting posture. J Phys Ther Sci. 2020;32(2):120–4.
21. Ortega-Pérez de Villar L, Martínez-Olmos FJ, Junqué-Jiménez A, Amer-Cuenca JJ, Martínez-Gramage J, Mercer T, et al. Test-retest reliability and minimal detectable change scores for the short physical performance battery, one-legged standing test and timed up and go test in patients undergoing hemodialysis. PLoS One. 2018;13:8. https://doi.org/10.1371/journal.pone.0201035.
22. Painter P, Carlson L, Carey S, Paul SM, Myll J. Physical functioning and health-related quality-of-life changes with exercise training in hemodialysis patients. Am J Kidney Dis. 2000;35(3):482–92.
23. Yabe H, Kono K, Yamaguchi T, Yamada N, Ishikawa Y, Yamaguchi Y, et al. Effect of intradialytic exercise on geriatric issues in older patients undergoing hemodialysis: a single-center non-randomized controlled study. Int Urol Nephrol. 2022;54(11):2939–48.
24. Matsufuji S, Shoji T, Yano Y, Tamaru A, Tsuchikura S, Miyabe M, et al. Difficulty in activities of daily living and falls in patients undergoing hemodialysis: a cross-sectional study with nondialysis controls. Hemodial Int. 2021. https://doi.org/10.1111/hdi.12930.
25. Watanabe T, Kutsuna T, Yoneki K, Harada M, Shimoda T, Matsunaga Y, et al. Determinants of difficulty in activities of daily living in ambulatory patients undergoing hemodialysis. Ren Replace Ther. 2018;4:8. https://doi.org/10.1186/s41100-018-0146-y.
26. Frimenko R, Goodyear C, Bruening D. Interactions of sex and aging on spatiotemporal metrics in non-pathological gait: a descriptive meta-analysis. Physiotherapy. 2015;101(3):266–72. https://doi.org/10.1016/j.physio.2015.01.003.
27. Wu T, Zhao Y. Associations between functional fitness and walking speed in older adults. Geriatr Nurs. 2021;42(2):540–3. https://doi.org/10.1016/j.gerinurse.2020.10.003.
28. Hara A, Kono K, Oshita H, Yabe Y, Moriyama Y, Yamada T. Representative value of nutritional status and physical function stratified by age and sex in maintenance hemodialysis patients. Phys Ther Jpn. 2020;47:207–14.
29. Shirai N, Yamamoto S, Osawa Y, Tsubaki A, Morishita S, Igarashi K, et al. Comparison of muscle strength between hemodialysis patients and non-dialysis patients with chronic kidney disease. J Phys Ther Sci. 2021;33(10):742–7.
30. Porto JM, Nakaishi APM, Cangussu-Oliveira LM, Freire Júnior RC, Spilla SB, Abreu DCC. Relationship between grip strength and global muscle strength in community-dwelling older people. Arch Gerontol Geriatr. 2019;82:273–8.
31. Leal VO, Mafra D, Fouque D, Anjos LA. Use of handgrip strength in the assessment of the muscle function of chronic kidney disease patients on dialysis: a systematic review. Nephrol Dial Transplant. 2011;26(4):1354–60.
32. Xavier JS, de Góes CR, Costa Borges MC, Caramori JCT, Vogt BP. Handgrip strength thresholds are associated with malnutrition inflammation score (MIS) in maintenance hemodialysis patients. J Ren Nutr. 2022;32(6):739–43.
33. Mae Y, Takata T, Yamada K, Hamada S, Yamamoto M, Iyama T, et al. Creatinine generation rate can detect sarcopenia in patients with hemodialysis. Clin Exp Nephrol. 2022;26(3):272–7.
34. Noce A, Marrone G, Ottaviani E, Guerriero C, Di Daniele F, Pietroboni Zaitseva A, et al. Uremic sarcopenia and its possible nutritional approach. Nutrients. 2021. https://doi.org/10.3390/nu13010147.
35. Kimura A, Paredes W, Pai R, Farooq H, Buttar RS, Custodio M, et al. Step length and fall risk in adults with chronic kidney disease: a pilot study. BMC Nephrol. 2022;23(1):74. https://doi.org/10.1186/s12882-022-02706-w.
36. Yabe H, Kono K, Yamaguchi T, Ishikawa Y, Yamaguchi Y, Azekura H. Effects of intradialytic exercise for advanced-age patients undergoing hemodialysis: a randomized controlled trial. PLoS ONE. 2021;22(16):10. https://doi.org/10.1371/journal.pone.0257918.

37. Mendes J, Borges N, Santos A, et al. Nutritional status and gait speed in a nationwide population-based sample of older adults. Sci Rep. 2018;8(1):4227. https://doi.org/10.1038/s41598-018-22584-3.
38. Yoshida Y, Iwasa H, Kumagai S, Yoshida H, Suzuki T. Association between C-reactive protein (CRP) level and physical performance in community-dwelling elderly in Japan. Arch Gerontol Geriatr. 2010;51(2):164–8. https://doi.org/10.1016/j.archger.2009.10.002.
39. Aung KC, Feng L, Yap KB, Sitoh YY, Leong IY, Ng TP. Serum albumin and hemoglobin are associated with physical function in community-living older persons in Singapore. J Nutr Health Aging. 2011;15(10):877–82. https://doi.org/10.1007/s12603-011-0120-7.
40. Johansen KL, Chertow GM, da Silva M, Carey S, Painter P. Determinants of physical performance in ambulatory patients on hemodialysis. Kidney Int. 2001;60(4):1586–91.
41. Marini ACB, Pimentel GD. Is body weight or muscle strength correlated with the Malnutrition Inflammation Score (MIS)? A cross-sectional study in hemodialysis patients. Clin Nutr ESPEN. 2019;33:276–8.
42. Inaba M, Okuno S, Ohno Y. Importance of considering malnutrition and sarcopenia in order to improve the QOL of elderly hemodialysis patients in Japan in the era of 100-year life. Nutrients. 2021. https://doi.org/10.3390/nu13072377.
43. Bündchen DC, Sousa H, Afreixo V, Frontini R, Ribeiro O, Figueiredo D, et al. Intradialytic exercise in end-stage renal disease: an umbrella review of systematic reviews and/or meta-analytical studies. Clin Rehabil. 2021;35(6):812–28.
44. Huang M, Lv A, Wang J, Xu N, Ma G, Zhai Z, et al. Exercise training and outcomes in hemodialysis patients: systematic review and meta-analysis. Am J Nephrol. 2019;50(4):240–54.
45. Abdelaal AAM, Abdulaziz EM. Effect of exercise therapy on physical performance and functional balance in patients on maintenance renal hemodialysis: randomized controlled study. J Exerc Rehabil. 2019;15(3):472–80.
46. Bakaloudi DR, Siargkas A, Poulia KA, Dounousi E, Chourdakis M. The effect of exercise on nutritional status and body composition in hemodialysis: a systematic review. Nutrients. 2020. https://doi.org/10.3390/nu12103071.
47. Martin-Alemañy G, Espinosa-Cuevas MLÁ, Pérez-Navarro M, Wilund KR, Miranda-Alatriste P, Cortés-Pérez M, et al. Effect of oral nutritional supplementation with and without exercise on nutritional status and physical function of adult hemodialysis patients: a parallel controlled clinical trial (AVANTE-HEMO study). J Ren Nutr. 2020;30(2):126–36.
48. Martin-Alemañy G, Perez-Navarro M, Wilund KR, García-Villalobos G, Gómez-Guerrero I, Cantú-Quintanilla G, et al. Effect of intradialytic oral nutritional supplementation with or without exercise improves muscle mass quality and physical function in hemodialysis patients: a pilot study. Nutrients. 2022. https://doi.org/10.3390/nu14142946.

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