Original Article

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Age, diabetes mellitus, and dialysis modality are associated with risk of poor muscle strength and physical function in hemodialysis and peritoneal dialysis patients

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Background: Due to the poor outcomes associated with the impairment of physical function and muscle strength in patients on maintenance dialysis, it is important to understand the factors that may influence physical function and muscle strength. The aim of this study was to explore the factors associated with physical function in hemodialysis and peritoneal dialysis patients.

Methods: Patients with chronic kidney disease on dialysis for at least 3 months, aged 18 years old or above, were enrolled. Physical function was assessed by handgrip strength, gait and sit-to-stand tests, and the Short Physical Performance Battery (SPPB). Clinical and laboratory data were collected to verify the association with physical function parameters through binary logistic regression.

Results: One-hundred ninety patients on maintenance dialysis were included; 140 patients (73.7%) on hemodialysis and 50 (26.3%) on peritoneal dialysis. The mean age was 57.3 ± 14.9 years, 109 (57.4%) were male, and 87 (45.8%) were older than 60 years. The median SPPB was 8.0 points (6.0–10.0 points) and the mean ± standard deviation of handgrip strength was 24.7 ± 12.2 kg. Binary logistic regression showed that age, type of renal replacement therapy, diabetes mellitus, and serum creatinine were significantly associated with both higher 4-meter gait test times and lower SPPB scores. Only age and diabetes mellitus were associated with higher sit-to-stand test times, while age and ferritin were associated with lower handgrip strength.

Conclusion: Age, diabetes mellitus, serum creatinine, and hemodialysis modality are factors related to physical function in dialysis patients.

Keywords: Chronic renal insufficiency, Dialysis, Hand strength, Physical functional performance, Physical performance

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Introduction

The prevalence of sarcopenia in chronic kidney disease (CKD) patients varies widely, ranging from 4.0% to 13.7% depending on the CKD stage, kidney replacement therapy (KRT), and the consensus version [1–3]. This number is even higher in CKD patients aged 60 years and above [3].

In this context, the assessment of physical function of CKD patients undergoing conservative treatment or who are on dialysis is extremely important. Deterioration of physical function is accelerated in patients with CKD, increasing the risk of worse outcomes, such as loss of independence, risk of morbidity, reduced quality of life, and reduced survival [4,5]. Recently, the association of poor physical function with mortality was verified in meta-analyses including nondialysis [5] and dialysis CKD patients, with an inverse association found between handgrip strength (HGS) and all-cause mortality [6].

Due to the importance of physical function and muscle strength for patients on maintenance dialysis, it is important to understand the factors that may influence these traits. As a consequence, patients at risk of diminished physical function and muscle strength may receive more attention from their health care team in order to improve or maintain such attributes. Therefore, our objective was to explore the factors associated with muscle strength and physical function in maintenance hemodialysis (HD) and peritoneal dialysis (PD) patients.

Methods

This was a cross-sectional analysis, which included participants with CKD on HD or PD from three protocols. These patients were either on (1) maintenance HD or PD in the Dialysis Unit from the Clinics Hospital of Botucatu Medical School (Botucatu, Brazil) or (2) maintenance HD in the Dialysis Service from the Presidente Prudente Regional Hospital (Presidente Prudente, Brazil). The three research protocols were approved by the respective Institution Research Ethics Committees (CAAE 71393717.7.0000.5411, 61634816.4.0000.5411, and 73640317.9.0000.5515) and the enrolled patients provided written informed consent.

The enrolled patients were on dialysis for at least 3 months and aged 18 years old or above. Patients who were bedridden, those with upper and lower limb sequelae, or amputees were excluded because they cannot perform the necessary physical performance assessments. Patients with other catabolic conditions were also excluded, such as neoplasia, final stage liver disease, severe heart diseases, or chronic obstructive pulmonary disease.

Age, sex, dialysis vintage, presence of diabetes mellitus (DM), dialysis adequacy (Kt/V), and routine laboratory tests (serum levels of urea, creatinine, albumin, cholesterol, triglycerides, hemoglobin, calcium, phosphorus, potassium, parathyroid hormone, iron, and ferritin) were collected from medical records.

Anthropometric evaluation consisted of actual body weight and height measurements for body mass index calculations. For this assessment, patients on PD had an empty peritoneal cavity and HD patients were evaluated after their dialysis session.

Muscle strength and physical function were evaluated in this study using a 4-meter gait test, sit-to-stand test, Short Physical Performance Battery (SPPB), and HGS test. All assessments were performed 30 minutes after the end of the HD session. Patients on PD were evaluated during routine care visits.

To assess the 4-meter gait test, patients had two attempts to walk a 4-meter course at their usual speed with static start. Each attempt was timed and the faster value was considered for the analyses [7]. The sit-to-stand test measures the amount of time the patient takes to rise five times from a straight-backed chair. Patients were instructed to stand up from the initial sitting position and sit down five times as quickly as possible, without using his or her arms [7]. Sit-to-stand tests require both muscle strength and endurance [8].

The SPPB consists of three different tests of lower-extremity function; balance test (ability to maintain for 10 seconds the following stand positions: feet together side-by-side, semi-tandem, and tandem), 4-meter gait test, and sit-to-stand chair test. A summary score ranging from 0 (worst performance) to 12 (best performance) was calculated [7].

HGS measurement was performed using a Jamar (Sammons Preston Rolyan, Bolingbrook, IL, USA) or Saehan hydraulic dynamometer (Saehan Corp., Changwon, Korea). These dynamometers are considered equivalents, with an intraclass correlation coefficient of >0.97 [9]. Patients were positioned with the dynamometer facing away from the body and the other arm extended to the side of the body. In the sequence, patients were instructed to hold the grip for around 3 seconds with maximum force in response to a voice command. Three measurements were performed, with intervals of around 30 seconds between each; the highest value was considered for analysis. The evaluation of patients on HD was performed on the side opposite from their arteriovenous fistula or central access. Patients on PD were evaluated through the dominant limb [10].

Statistical analysis

Data are expressed as mean ± standard deviation or median (interquartile range), according to the variables' distribution. Frequencies are expressed as percentages. In order to compare patients according to age, presence of DM, and method of dialysis, Student t test, Mann-Whitney test, or chi-square test were used.

The correlations between clinical and laboratory variables with muscle strength and physical function were assessed by Spearman or Pearson correlation coefficients. To address associated factors, four models of binary logistic regression were built, each one with a muscle strength or physical function parameter as a dependent variable (4-meter gait time, sit-to-stand test time, SPPB total score, and HGS) categorized by the respective median. HGS was categorized according to the median by each sex. Parameters correlated with the dependent variables ($p < 0.2$) in univariate analysis were selected to be included in the logistic regression models.

Statistical significance was considered when $p < 0.05$. Analyses were performed using IBM SPSS version 22.0 (IBM Corp., Armonk, NY, USA).

Results

One-hundred ninety patients on maintenance dialysis were enrolled, with 140 patients (73.7%) on HD and 50 (26.3%) on PD. The PD modality used by most patients was continuous cycling PD (CCPD) (60.0%, n = 30), followed by Nocturnal Intermittent PD modality (36.0%, n = 18), and continuous ambulatory PD modality (4.0%, n = 2). The majority of the patients (57.4%) were males, and 87 individuals (45.8%) were older than 60 years. Demographic, clinical, and laboratory characteristics, as well as physical function scores of the patients, are presented in Table 1.

Patients were compared according to dialysis method. Dialysis vintage, serum urea, creatinine, albumin, and potassi-

Table 1. Characteristics of the enrolled patients

Characteristic	Data
Patients	190
Age (yr)	57.3 ± 14.9
Sex	
Female	81 (42.6)
Male	109 (57.4)
Diabetes mellitus	60 (31.6)
Dialysis vintage (mo)	20.6 (8.8–59.7)
Kt/V[a], /wk	
PD	2.2 ± 0.5
HD	1.3 ± 0.3
Weight (kg)	70.3 ± 15.4
Body mass index (kg/m²)	26.4 ± 4.9
SPPB score	
Balance test	4.0 (3.0–4.0)
4-Meter gait test	3.0 (2.0–4.0)
Sit-to-stand test	1.0 (1.0–2.0)
SPPB total score	8.0 (6.0–10.0)
4-Meter gait test (sec)[b]	5.2 (4.2–6.6)
Sit-to-stand test (sec)[c]	17.6 (14.3–21.7)
Handgrip strength (kg)	24.7 ± 12.2
Male	31.1 ± 11.5
Female	16.0 ± 6.4
Urea (mg/dL)	120.1 ± 36.4
HD	127.4 ± 37.2
PD	99.5 ± 24.7
Creatinine (mg/dL)	10.0 ± 3.2
HD	10.3 ± 3.2
PD	9.0 ± 2.8
Albumin (g/dL)	3.8 ± 0.4
Hemoglobin (g/dL)	11.1 ± 1.7
Calcium (mg/dL)	9.1 ± 0.8
Phosphorus (mg/dL)	5.4 ± 1.4
Potassium (mmol/L)[d]	5.1 ± 0.9
Iron (μg/dL)	64.0 (49.8–91.0)
Ferritin (μg/dL)	278.7 (133.2–573.3)
PTH (pg/mL)	297.8 (175.1–592.5)
Cholesterol (mg/dL)	
Total	143.4 ± 38.1
HDL	37.0 (31.0–47.0)
LDL[e]	71.0 ± 31.0
Triglycerides (mg/dL)	143.0 (98.0–205.5)

Data are expressed as number only, mean ± standard deviation, number (%), or median (interquartile range). HD, hemodialysis; HDL, high-density lipoprotein; LDL, low-density lipoprotein; PD, peritoneal dialysis; PTH, parathyroid hormone; SPPB, Short Physical Performance Battery.
[a]n = 182 (PD, 48; HD, 134), [d]n = 184, [e]n = 187. [b]Four patients were not able to perform the 4-meter gait test. [c]Thirty-two patients were not able to perform the sit-to-stand test.

um were significantly higher in HD patients. Serum calcium, iron, ferritin, and high-density lipoprotein (HDL)-cholesterol were significantly lower in HD patients.

Comparison of physical function variables between patients according to age (younger or older than 60 years), presence of DM, and dialysis method (PD and HD) are presented in Table 2.

There was a significant correlation among all physical function parameters; the time of the 4-meter gait test was positively correlated with the sit-to-stand test ($r = 0.17$, $p = 0.02$) and negatively correlated both with the SPPB total score ($r = –0.72$, $p < 0.001$) and HGS ($r = –0.41$, $p < 0.001$). The sit-to-stand test was negatively correlated with SPPB total score ($r = –0.15$, $p = 0.04$). The SPPB total score was positively correlated with HGS ($r = 0.47$, $p < 0.001$). Correlations between physical function parameters and other variables are presented in Table 3.

For the binary logistic regression, times for the 4-meter gait test were categorized by the median, 5.22 seconds. Sex, age, type of KRT, dialysis vintage, DM, serum creatinine, urea, phosphate, and ferritin were included in the model. Sit-to-stand test times were categorized by the median of 17.56 seconds and SPPB was categorized by its median of 8 points. The same variables were included in each model; sex, age, type of KRT, DM, serum creatinine, urea, ferritin, albumin, and HDL-cholesterol.

HGS was categorized according to the median for each sex; 30 kg for male and 15 kg for female. The variables included in the model were sex, age, dialysis vintage, DM, Kt/V, serum creatinine, urea, calcium, potassium, hemoglobin, ferritin, albumin, and HDL-cholesterol.

The variables included in the final model were those that improved the model predictive capacity. In the final models, age, type of KRT (HD), DM, and serum creatinine were significantly associated with both a higher 4-meter gait test time and lower SPPB (models 1 and 3, respectively) (Table 4). Only age and DM were associated with a higher sit-to-stand test time (model 2), while age and ferritin were associated with a lower HGS (model 4) (Table 4).

DISCUSSION

The objective of this study was to identify the factors that are associated with muscle strength and physical function, assessed by four parameters in patients receiving dialysis treatment for at least 3 months. The results indicate that aging, DM, lower serum creatinine, and HD modality are factors related to poor muscle strength and physical function. Age was associated with all muscle strength and physical function tests performed in the study. DM, HD modality, and serum creatinine were associated with three of the four tests.

Aging is a well-known feature associated with worsening muscle strength and physical function in the general population [11]. Moreover, a natural decrease in muscle mass, strength, and performance occurs with aging; however, multiple other conditions contribute to such decrease [12]. Aging is considered a condition that leads to a proinflammatory state. The increased cytokine levels affect muscle protein synthesis, leading to muscle mass loss [13]. Lower muscle strength has been associated with increased interleukin-6 and C-reactive protein levels in older adults [14]. CKD uremia and dialysis are also known to promote inflammation, which may act synergistically with the effects of 'inflammaging' and lead to poor physical function.

In fact, among dialysis patients, older patients present worse physical function compared to younger patients [15,16]. Our results have shown age as an independent predictor of all parameters used to assess muscle strength and physical function in this study. Moreover, the decline in physical function related to aging often leads to loss of independence and ability to perform activities of daily life, as well as poorer quality of life [17]. Poor physical function is associated with increased risk of outcomes such as cognitive impairment, institutionalization, falls [18], disability [7], cardiovascular events [19], and mortality [7,20]. Therefore, elderly people on KRT should receive greater attention from their health care team and interventions should be proposed.

One of the comorbidities affecting physical function is DM. In our results, DM was associated with SPPB and the sit-to-stand and gait tests, but not with HGS. DM may affect muscle function through several mechanisms. Peripheral insulin resistance decreases the glucose uptake to muscle and reduces muscle tissue anabolic rates [13]. Also, changes in microvascularization decrease blood flow to the muscles. Moreover, other prevalent comorbidities (such as decreased vision, heart failure, neuropathy, and peripheral vascular disease) result in decreased physical activity and may also explain decreased physical function among the dialysis population [21,22]. However, the prevalence of these elements was not assessed in the current study.

Table 2. Comparison of clinical and physical function parameters between the groups according to age, diabetes mellitus, and dialysis method

Variable	Age (yr)			Diabtes mellitus			Dialysis method		
	<60 (n = 103)	≥60 (n = 87)	p-value	Yes (n = 60)	No (n = 130)	p-value	Peritoneal (n = 50)	Hemo (n = 140)	p-value
Age (yr)	46.7 ± 10.8	69.9 ± 7.3	<0.001	63.2 ± 11.3	54.6 ± 15.6	<0.001	55.7 ± 16.2	57.9 ± 14.4	0.38
Diabetes melliuts	24 (23.3)	36 (41.4)	0.008	–	–	–	14 (28.0)	46 (32.9)	0.53
Dialysis vintage (mo)	16.0 (7.2–42.9)	34.3 (11.0–65.6)	0.02	30.0 (11.3–57.7)	18.0 (7.2–63.9)	0.30	9.5 (5.0–18.0)	35.9 (12.7–71.3)	<0.001
Body mass index (kg/m²)	26.0 ± 4.9	26.9 ± 5.0	0.20	28.0 ± 5.2	25.6 ± 4.6	0.002	26.0 ± 4.5	26.5 ± 5.1	0.51
Balance test (score)	4.0 (4.0–4.0)	4.0 (1.0–4.0)	<0.001	2.0 (2.0–3.0)	4.0 (4.0–4.0)	<0.001	4.0 (4.0–4.0)	4.0 (2.0–4.0)	<0.001
4-Meter gait test[a]									
Time (sec)	4.5 (3.9–5.7)	6.2 (4.7–7.9)	<0.001	6.4 (4.9–8.0)	4.7 (4.1–6.2)	<0.001	4.6 (4.1–5.5)	5.6 (4.3–6.9)	0.02
Score	4.0 (3.0–4.0)	3.0 (2.0–4.0)	<0.001	2.0 (2.0–3.0)	4.0 (2.8–4.0)	<0.001	4.0 (3.0–4.0)	3.0 (2.0–4.0)	<0.001
>5.22 sec	36 (36.0)	57 (66.3)	<0.001	42 (72.4)	51 (39.8)	<0.001	16 (32.0)	77 (56.6)	0.003
Sit-to-stand test[b]									
Time (sec)	16.3 (13.0–19.6)	19.9 (16.6–23.4)	<0.001	20.4 (16.9–23.3)	16.9 (13.4–20.3)	0.001	16.4 (13.0–20.2)	18.1 (14.8–22.7)	0.02
Score	1.0 (1.0–3.0)	1.0 (1.0–1.0)	<0.001	1.0 (0–1.0)	1.0 (1.0–2.3)	<0.001	1.5 (1.0–3.0)	1.0 (1.0–2.0)	<0.001
>17.56 sec	34 (37.0)	45 (68.2)	<0.001	30 (68.2)	49 (43.0)	0.01	21 (42.0)	58 (53.7)	0.17
SPPB									
Total score	9.0 (7.0–11.0)	7.0 (4.0–8.0)	<0.001	6.5 (4.0–8.0)	9.0 (7.0–10.0)	<0.001	9.0 (8.0–11.0)	7.0 (5.0–9.0)	<0.001
<8 Points	27 (26.2)	53 (60.9)	<0.001	42 (70.0)	38 (29.2)	<0.001	9 (18.0)	71 (50.7)	<0.001
Low or weak handgrip strength (kg)	28.3 ± 12.8	20.4 ± 10.1	<0.001	21.4 ± 10.3	26.2 ± 12.8	0.01	25.7 ± 11.8	24.3 ± 12.4	0.50
Low or weak handgrip strength[c]	30 (29.1)	66 (75.9)	<0.001	41 (68.3)	55 (42.3)	0.001	17 (34.0)	79 (56.4)	0.006

Data are expressed as mean ± standard deviation, number (%), or median (interquartile range).
SPPB, Short Physical Performance Battery.
[a]Four patients were not able to perform the 4-meter gait test. [b]Thirty-two patients were not able to perform the sit-to-stand test. [c]Male, <30 kg; female, <15 kg.

Table 3. Correlation of physical function with different variables

Variable	4-Meter gait test (sec)		Sit-to-stand (sec)		SPPB (total score)		Handgrip strength (kg)	
	r	p	r	p	r	p	r	p
Age	0.49	<0.001	0.45	<0.001	−0.51	<0.001	−0.38	<0.001
Body mass index	−0.04	0.62	0.04	0.66	0.04	0.60	0.09	0.24
Dialysis vintage	0.22	0.002	−0.05	0.50	−0.30	<0.001	−0.18	0.01
Kt/V	0.05	0.52	−0.02	0.79	0.07	0.36	−0.19	0.01
Creatinine	−0.31	<0.001	−0.20	0.01	0.32	<0.001	0.40	<0.001
Urea	−0.11	0.13	−0.10	0.20	0.09	0.24	0.14	0.06
Calcium	0.07	0.35	0.07	0.36	−0.03	0.68	−0.15	0.04
Phosphorus	−0.17	0.02	−0.09	0.25	0.13	0.08	−0.02	0.82
Parathyroid hormone	−0.09	0.23	−0.04	0.62	0.03	0.64	0.04	0.63
Potassium	0.02	0.79	0.03	0.76	−0.05	0.50	0.20	0.007
Iron	−0.08	0.29	−0.04	0.66	0.18	0.01	0.10	0.16
Ferritin	0.12	0.10	0.13	0.11	−0.16	0.03	−0.21	0.003
Cholesterol								
Total	−0.02	0.82	−0.02	0.80	0.06	0.44	−0.09	0.23
HDL	−0.03	0.67	−0.14	0.07	0.07	0.34	−0.13	0.08
LDL	0.01	0.87	0.03	0.70	0.03	0.71	−0.11	0.15
Triglycerides	−0.02	0.77	−0.04	0.60	0.05	0.54	0.10	0.19
Hemoglobin	0.09	0.24	0.02	0.82	−0.08	0.33	0.11	0.14
Albumin	0.00	0.98	0.14	0.08	−0.08	0.28	0.17	0.02

HDL, high-density lipoprotein; LDL, low-density lipoprotein; SPPB, Short Physical Performance Battery.

Table 4. Binary logistic regressions with physical function parameters as dependent variables

Model	Dependent variable	Independent variable	OR (95% CI)	p-value
1	4-Meter gait test	Age	1.07 (1.04–1.11)	<0.001
	>5.22 sec (n = 186)	Dialysis modality (HD)	5.13 (2.09–12.62)	<0.001
		Diabetes mellitus	2.63 (1.19–5.79)	0.02
		Serum creatinine	0.85 (0.74–0.97)	0.02
2	Sit-to-stand test	Age	1.07 (1.03–1.10)	<0.001
	>17.56 sec (n = 157)	Diabetes mellitus	2.31 (1.04–5.11)	0.04
		Male	1.77 (0.85–3.69)	0.13
3	SPPB	Age	1.12 (1.07–1.17)	<0.001
	<8 points (n = 186)	Dialysis modality (HD)	20.13 (5.69–71.18)	<0.001
		Diabetes mellitus	4.73 (1.90–11.78)	0.001
		Serum creatinine	0.74 (0.61–0.88)	0.001
4	Handgrip strength	Age	1.14 (1.10–1.19)	<0.001
	<30 kg in male or <15 kg in female	Ferritin	1.001 (1.00–1.003)	0.004

CI, confidence interval; HD, hemodialysis; SPPB, Short Physical Performance Battery; OR, odds ratio.

Serum creatinine was a significant predictor of physical function in the models with the 4-meter gait test and SPPB as dependent variables. Serum creatinine may reflect muscle mass of patients on dialysis [23]. Muscle function declines at a rate different from that of muscle size [24], and the worse physical function of patients on HD compared to non-CKD elderly was not explained by muscle size [22]. Nonetheless, a recent systematic review discusses how the association between physical function and muscle size in CKD patients is still controversial [25].

The current study found that HD patients have a higher risk of reduced muscle strength and poor physical function compared to PD patients. In a systematic review, Purnell et al. [26] showed no significant differences in physical function in 76% of comparisons between these two KRT modalities. However, the majority of the included studies used 36-Item Short Form Survey (SF-36) domains to assess physical function; such methodology is considered a subjective assessment. A comparison of quality of life between HD and PD patients using SF-36 has not found differences between the KRT modalities [27]. Moreover, none of the studies included in the systematic review [26] used the same objective assessments used in the current study (gait test, sit-to-stand test, SPPB, or HGS).

The characteristics of each KRT modality may influence physical function through the daily routine imposed by the treatment. Most PD patients have some free time during the day, with one or two dialysate changes per day on CCPD modality. On the other hand, HD patients spend many hours, 3 days a week, with no activities during transit to the HD center and during the HD session. Moreover, frequent symptoms after HD sessions, such as bleeding, hypotension, dizziness, fatigue, etc., increase the need for rest. Thus, these factors related to HD therapy may favor a more sedentary lifestyle, and intradialytic interventions aimed at physical function improvement could be useful.

Another issue related to KRT modality is the assessment timing. In our study, HD patients were assessed after the HD session. At this time, hypotension, dizziness, and fatigue may affect the results of the physical function tests. However, before the dialysis session, the patients are overhydrated, which may also influence the results of the performance tests [28]. Pinto et al. [29] compared HGS before and after HD sessions and concluded that the HD procedure negatively affects HGS. Moreover, HGS variation was correlated with blood pressure variations. On the other hand, Leal et al. [30] found no difference between HGS values before and after HD sessions. Dialysis variables, such as ultrafiltration, inter-dialytic body weight gain, Kt/V, urea, and blood pressure were not correlated with HGS values [30]. Some studies assessed physical function before [31,32] or after [10,33] dialysis session, and others on nondialysis days [22]. Therefore, there is no standard for physical function assessment timing.

Assessments of muscle strength and physical function can be done by different methods in CKD. Sit-to-stand tests, 4-meter gait speed tests, SPPB, and HGS were chosen for this study based on the ease and practicality of performing these tests, even in dialysis unit facilities. These tests reflect common daily living activities, i.e., getting up from a chair or walking small distances. SPPB and HGS assessments were previously shown to be reliable in HD patients [31,32] and both have been recommended by the European Working Group on Sarcopenia in Older People 2 (EWGSOP2) for sarcopenia diagnosis [8]. However, there are no specific cutoffs for physical function assessments among the CKD population.

In a comparison between patients with low and appropriate muscle strength, Isoyama et al. [34] observed that those with low strength were older and had more comorbidities, such as cardiovascular disease and DM, lower serum creatinine, and higher inflammatory markers levels. Furthermore, HGS has been considered an independent predictor of all-cause mortality in HD and PD patients [10,34], which was recently confirmed by Hwang et al. [6] in a meta-analysis. They found that patients with low HGS had a 1.88-fold higher risk of death than those with higher HGS. In addition, a 1-kg unit increase in HGS was associated with a 5% reduction in the risk of mortality [6].

As poor physical function is associated with poorer outcomes in the dialysis population, interventions that improve physical function may decrease the risk of poor outcomes. Exercise training is the most investigated intervention, and several modalities have been tested.

A recent meta-analysis [35] reported that either aerobic or resistance exercise modalities could improve objective measures of physical function in patients undergoing dialysis. Additionally, intradialytic exercise improved physical function more efficiently than interdialytic exercise, supporting the hypothesis of intradialytic exercise interventions for HD patients [35]. Intradialytic resistance band exercise training and neuromuscular electrical stimulation were also effective interventions to enhance physical function in patients on HD [35–37]. It is important to highlight that previous studies have shown exercise interventions are safe and well-tolerated [36], with no significant changes in hemodynamic parameters [38] and no adverse events during the training session [39].

There are fewer studies with exercise interventions in PD. Although the physical function of these patients is better than in HD patients, exercise could bring other benefits to this population as well as to HD patients. In a randomized controlled trial in PD patients, a 12-week home-based program that included aerobic and resistance exercise was effective in improving aerobic capacity, some domains of quality of life, serum albumin, and insulin resistance [40].

Combined interventions, such as nutritional supplementation and exercise, offer strategies to improve muscle strength and physical function. Martin-Alemañy et al. [41] showed that the combination of oral nutritional supplementation with aerobic or resistance intradialytic exercise had better effects on physical function than supplementation alone in young HD patients. Due to the association of vitamin D status with muscle health and the high prevalence of vitamin D deficiency in CKD, Olvera-Soto et al. [42] added cholecalciferol supplements to a resistance exercise program intervention in stage 4 CKD patients. A significant increase in HGS was observed. Those strategies are still incipient in CKD research. Therefore, more trials are necessary to assess such effects.

A limitation of this study is the merging of three different data sets of HD and PD patients from two centers. Nonetheless, in all of these data sets, the assessments were obtained using the same protocol. The cross-sectional design may also be a limitation since it is not possible to demonstrate the relationship between cause and effect.

In conclusion, age, DM, and dialysis modality are factors related to muscle strength and physical function in dialysis patients. Thus, special attention should be given to patients with these characteristics, and specific interventions should be tested with the objective to improve muscle strength and physical function in both HD and PD patients.

Conflicts of interest

All authors have no conflicts of interest to declare.

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