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The impact of intradialytic elastic band exercise on physical and cognitive abilities in patients on maintenance hemodialysis: a randomized controlled trial

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ABSTRACT
Exercise benefits patients on maintenance hemodialysis (MHD) by addressing complications and dysfunctions. Elastic band exercise is cost-effective, but its safety, efficacy, and feasibility during dialysis are not well-established. The aim of this study is to investigate the physical and mental effects of intradialytic elastic band exercise in patients on MHD. Sixty patients on MHD were randomly assigned to the exercise or control group (30 patients/group). The control group received routine hemodialysis care, whereas those in the exercise group performed intradialytic elastic band exercises for 0.5–2 h during hemodialysis three times a week for 12 weeks. Physical function (Short Physical Performance Battery [SPPB]), cognitive function (Montreal Cognitive Assessment [MoCA]), fatigue (14-item Fatigue Scale [FS-14]), sleep quality (Pittsburgh Sleep Quality Index [PSQI]), and anxiety and depression (Hamilton Anxiety Rating Scale [HAMA]/Hamilton Depression Rating Scale [HAMD]) were assessed. The exercise group showed significant improvements in SPPB ($p = 0.008$) and MoCA ($p < 0.001$) scores compared to pre-intervention and control groups. FS-14 scores decreased significantly ($p = 0.005$). PSQI ($p < 0.001$) and HAMA ($p < 0.001$) scores improved post-intervention but not versus control. HAMD scores reduced significantly ($p < 0.001$). Satisfaction and recommendation scores were 9.57 and 9.71. In conclusions, intradialytic elastic band exercise improved physical and cognitive function and alleviated fatigue, sleep issues, depression, and anxiety in patients on MHD. With high compliance, no significant adverse events, and high patient satisfaction, it is recommended as a routine intervention during dialysis.

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Introduction

Maintenance hemodialysis (MHD) is a primary treatment option for patients with end-stage renal disease (ESRD), as it effectively alleviates uremia symptoms and prolongs patient survival [1,2]. However, because of toxin accumulation, a micro-inflammatory state, metabolic disorders affecting nerve cell function, and cerebral ischemia from hemodynamic changes during dialysis, patients on MHD often experience multiple types of dysfunctions [3–7]. Despite its benefits, hemodialysis has not significantly improved physical functioning and social participation among patients on MHD. Consequently, their health status remains unsatisfactory, and the crude mortality rate for patients with ERSD in recent years is approximately 10%.

Patients on MHD frequently experience adverse reactions on dialysis days, including muscle cramps, arrhythmia, nausea, vomiting, post-dialysis hypotension, and fatigue [8]. As the duration of dialysis increases, patients also experience varying degrees of physical, cognitive, and psychological dysfunction, significantly impacting their quality of life [9].

Studies indicate that the activity level of with patients on MHD is 10–40% lower on dialysis days than on non-dialysis days, contributing to low physical function and insufficient physical activity [10]. Approximately 70–80% of patients on MHD experience cognitive dysfunction, and this rate is more than 3-fold higher than that of people with normal renal function [11,12]. Additionally, patients on MHD are prone to

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fatigue, sleep disorders [13,14], depression, and anxiety [15,16]. The Standardized Outcomes in Kidney Disease initiative has highlighted that patients on MHD prioritize improvements in sleep quality, mobility, and fatigue [17,18]. Therefore, enhancing the quality of life and reducing complications for patients on dialysis have become critical issues in nephrology.

Guidelines consistently recommend regular exercise for patients on MHD, including exercise during dialysis [19]. Intradialytic exercise, considered the "fifth parameter of exercise prescription" for patients on MHD, is widely advocated because of its numerous benefits. Elastic bands represent a more economical option than treadmills or stationary bikes, offering minimal purchase and maintenance expenses for both dialysis centers and patients. Additionally, the dialysis setting provides a controlled and supervised environment that ensures safety and high compliance. By reducing the sedentary time associated with hemodialysis, elastic band exercises are particularly well-suited for implementation in dialysis centers [20]. Despite the popularity of elastic band exercise in rehabilitation medicine because of its unique advantages, there is limited research on its application and effects among patients on dialysis. This study aimed to investigate the impact of elastic band exercise during dialysis on patients undergoing MHD with a focus on its effects on physical function and mental health.

Methods

Design and participants

This study was a prospective, single-center, randomized, controlled, interventional trial. It was approved by the Clinical Research Center of Shanghai Sixth People's Hospital (No. 2022-KY-173(K)) and registered with the Chinese Clinical Trial Registry (No. ChiCTR2300067852).

Conducted at the hemodialysis center of Shanghai Sixth People's Hospital, the study screened all patients aged ≥18 years who had been on hemodialysis for more than 3 months for eligibility based on the inclusion and exclusion criteria. Eligible patients were approached by a team member and invited to participate. Enrollment required willingness to sign the consent form and complete the baseline assessment.

The recruitment period spanned February 2023 to June 2023. All participants provided written informed consent after receiving an explanation of the study. They were free to withdraw at any time without affecting their hemodialysis care. All data remained confidential throughout the study.

Participant recruitment

Participants meeting the selection criteria were recruited and randomly assigned to the control or exercise group. The inclusion criteria were as follows: age ≥ 18 years, completion of three hemodialysis sessions per week for at least 3 months, muscle strength of grade 3 or higher, stable medical condition, normal mental status and intelligence, clear consciousness, willingness to participate, and consent to randomization. A stable medical condition was defined as the absence of significant changes in a patient's health status for at least one month prior to enrollment, including no recent hospitalizations for major hemodialysis-related complications and no acute exacerbations of comorbidities.

The exclusion criteria were as follows: uncontrolled arterial hypertension (blood pressure > 180/110 mmHg) or hypotension (blood pressure < 90/60 mmHg), severe cardiopulmonary disease (e.g., heart failure, arrhythmia, unstable angina, severe pericardial effusion, valvular stenosis, hypertrophic cardiomyopathy, aortic coarctation), uncontrolled pulmonary hypertension (mean pulmonary artery pressure > 55 mmHg), acute clinical events (e.g., acute systemic inflammatory disease, fever, acute cardiovascular events, acute traumatic injuries), symptoms of new deep vein thrombosis, inability to cooperate with exercise, muscle or joint pain in the lower limbs, femoral vein placement, unstable hemodialysis or noncompliance to hemodialysis, and psychological disorder or dementia.

The withdrawal criteria included a loss of interest in the study, scheduling conflicts, serious adverse effects from treatment, development of other serious illnesses (e.g., stroke), withdrawal of consent, and circumstances deemed by the investigator to warrant withdrawal from the study.

Sample size

The sample size calculation was based on a previous study [21], with the primary outcome being the assessment of patients' MoCA scores. An *a priori* power analysis was conducted using G*Power 3.0 to determine the appropriate sample size [22]. Based on an independent-samples *t*-test with an effect size of 0.25, an alpha level of 0.05, a power of 0.8, and a 1:1 group ratio, the required sample size was calculated to be 52 participants [23]. To account for a potential 15% dropout rate, the final plan was to include 60 patients on MHD, with 30 allocated to each group.

Randomization

Participants were allocated to either the intradialytic exercise or control group using simple random sampling with SPSS, aiming for an approximately equal distribution between the groups. Random allocation in SPSS assigned participants to the intradialytic exercise group (value 1) or control group (value 2). The randomization and group assignments were generated by a researcher not involved in participant recruitment or assessment to ensure impartiality.

Measurements

Demographic and clinical characteristics including age, sex, education, employment status, and marital status were recorded. Additional pre-hemodialysis medical factors (e.g., patients' preexisting comorbidities such as hypertension, diabetes, cardiovascular diseases), dialysis factors (dialysis vintage), and clinical measures were obtained from the dialysis medical records.

Cognitive function was assessed using the Montreal Cognitive Assessment (MoCA) [24], which evaluates attention and concentration, memory, orientation, language, visuospatial skills, conceptual thinking, calculations, and executive functions [25,26]. Physical performance was measured using the Short Physical Performance Battery (SPPB) The SPPB is a standardized, comprehensive scale for assessing physical function, consisting of three tests: the balance test, the 4-meter walk test, and the 5-time sit-to-stand test (5-STS) [27]. Fatigue was evaluated using the 14-item Fatigue Scale (FS-14), whereas sleep quality was assessed using the Pittsburgh Sleep Quality Index (PSQI) [28]. Anxiety and depression were measured with the Hamilton Anxiety Rating Scale/Hamilton Depression Rating Scale (HAMA/HAMD) [29,30]. More details about the evaluation tools used are listed in the Table 1.

All participants attended two measurement sessions: one at study entry (baseline, prior to randomization) and one after the 12-week intervention period (post-test). The same assessors, who were blinded to treatment allocation, conducted all endpoint assessments. Data collection was performed at the hemodialysis center in Shanghai Sixth People's Hospital.

Intervention

Control group

Patients in the control group received usual care, which allowed all standard treatments to continue unchanged. During dialysis, participants in the control group rested in a flat position, except for necessary physical activities, and they did not engage in any additional exercise interventions.

Exercise group

The exercise group performed intradialytic elastic band exercises during each hemodialysis session, three times a week for 12 weeks, in addition to routine hemodialysis treatment and care. After 30 min on hemodialysis, research staff approached participants to initiate the intervention. Participants engaged in elastic band exercises for at least 30 min during each session.

Prior to exercise, patients' physical conditions were assessed to ensure suitability for exercise. The duration and intensity of each exercise session, along with any adverse effects, were recorded by the study staff.

The intradialytic exercise sessions were predetermined by the study manager and consisted of low-to-moderate-intensity training combining aerobic and strength exercises [31]. Exercise intensity was measured using the Borg Scale (rating of perceived exertion [RPE]), a reliable tool for assessing exercise intensity, and its score ranges from 6 (no exertion) to 20 (maximal exertion) [32]. Before patients began the exercise program, our research staff explained the meaning and usage of the Borg Scale and demonstrated how to assess their perceived exertion during exercise. Additionally, patients were asked to practice using the scale during the initial exercise sessions to ensure accurate reporting of their exercise intensity.

Warm-up exercise

Participants began with 5–10 min of lower-limb and joint stretching, maintaining a perceived exertion level of 8 to 9 (very light exertion).

Main exercise

The main exercise lasted for 30–40 min and consisted of four movements targeting lower body muscles with dynamic movement coordination. Movements were performed slowly and strongly, alternating between lower limbs, with at least 20 s of rest between each set (or longer if fatigue was present). Participants performed the exercises in a supine

Table 1. Implications of the research indicators.

Research indicators	Assessment tools	Tool details	Scoring instructions
Physical Function	Short Physical Performance Battery (SPPB)	A standard comprehensive physical function testing tool, including balance test, 4-meter gait speed test and sit-to-stand test	Each of the three parts is scored from 0 to 4 points, with a total score of 12 points. The higher the score, the better the patient's physical function.
Cognitive Function	Montreal Cognitive Assessment (MoCA)	Covers seven dimensions: visuospatial and executive function, naming, attention, language, abstraction, delayed recall and orientation	The full score of the scale is 30 points. The higher the score, the better the cognitive function. A score less than 26 points indicates possible cognitive decline.
Fatigue Level	Fatigue Scale-14 (FS-14)	The content is divided into two dimensions: physical fatigue and mental fatigue	The maximum scores of the two dimensions are 8 points and 6 points respectively, and the maximum total score is 14 points. The higher the score, the more severe the recent fatigue level.
Sleep Quality	Pittsburgh Sleep Quality Index (PSQI)	There are a total of 7 dimensions of sleep components, comprehensively evaluating the overall sleep quality of subjects from different aspects	The higher the score, the worse the sleep quality.
Psychological Status	Hamilton Anxiety/ Depression Scale (HAMA/HAMD)	Used to assess anxiety and depression respectively	A score of HAMA or HAMD greater than 7 points indicates possible anxiety or depression. The higher the score, the more severe the patient's anxiety or depression.
Biochemical Indicators	Peripheral Venous Blood Collection and Testing	Collect peripheral venous blood from patients before and after the start of the study	Check the levels of hemoglobin, albumin, calcium, phosphorus and serum potassium of patients.

position with a Thera-band (15 or 20 lb) secured to the end of the bed and attached to their ankles.

Exercises

Session 1. Knee flexion and extension resistance exercise: Participants slowly flexed and extended the knee joint, keeping the foot on the bed, flexing the knee to approximately 90 degrees, after which the leg was straightened and placed flat on the bed (Figure 1).

Session 2. Supine straight-legged raise resistance exercise: Participants straightened the knee joint, lifted the leg off the bed, and slowly lowered it after feeling resistance (Figure 2).

Session 3. Supine hip abduction resistance exercise: Participants straightened the knee joint, lifted the leg off the bed, abducted the hip joint by opening the leg outward until resistance was felt, and then returned the knee joint to the starting position (Figure 3).

Session 4. Hip flexion and extension resistance exercise: Participants flexed the knee and hip, lifted the foot off the bed, and flexed the hip toward the abdomen until resistance was felt, and returned the knee joint to the starting position (Figure 4).

Patients exercised three times per week during dialysis under the supervision of an exercise physiologist. Each training session consisted of a minimum of three sets of 20–30 repetitions for each of the four exercises with a 30-s interval between sets on each side. The intensity was maintained at a perceived exertion level of 11–13 (somewhat hard exertion) [33,34]. If the perceived exertion scale was lower than 12, then participants were encouraged to increase the intensity.

The exercise physiologist adjusted the number of repetitions, sets, and training loads according to the patient's strength and tolerance improvements. The progression of load and duration was individualized according to each patient's RPE response and their motivation.

The session concluded with a cool-down exercise comprising 5–10 min of massage, which involved stretching or patting the muscles with an intensity level of 8–9 (very light exertion). Patients' reactions were monitored every 20 min during exercise and 5–10 min after exercise. Exercise was promptly stopped if patients experienced adverse reactions such as chest tightness, dizziness, or muscle and joint pain.

Adverse events

In the exercise group, the expected adverse events included cardiovascular issues (e.g., hypotension, hypertension, arrhythmia), joint muscle injuries (e.g., muscle soreness, cramps, joint pain), headaches, and other potential adverse events (e.g., skin abrasions from the elastic band's contact with the skin, any symptoms occurring during or immediately after exercise not previously mentioned). During every session, participants were asked to report any of these expected adverse events. All unexpected adverse events were identified through direct observation, interviews with participants, and unsolicited reports from participants or dialysis staff. These adverse events

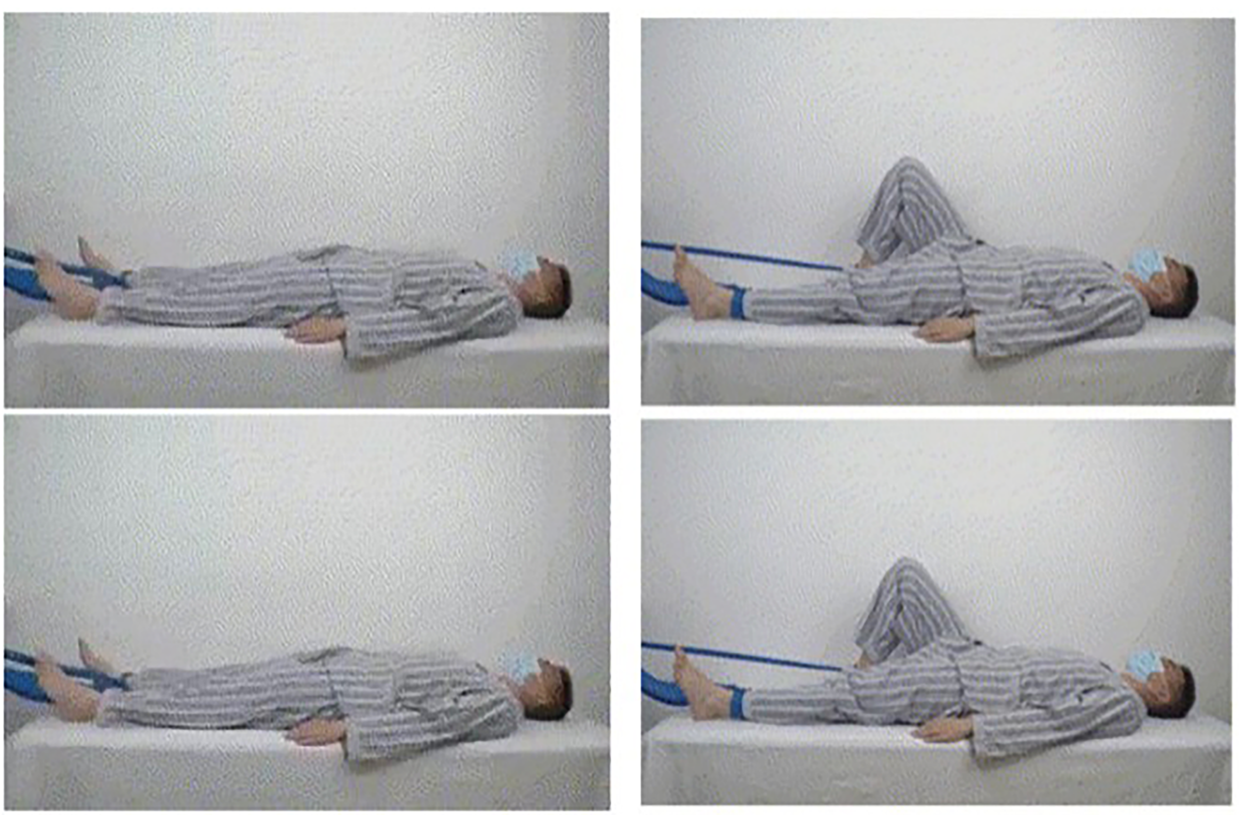

Figure 1. Knee flexion and extension resistance exercise.

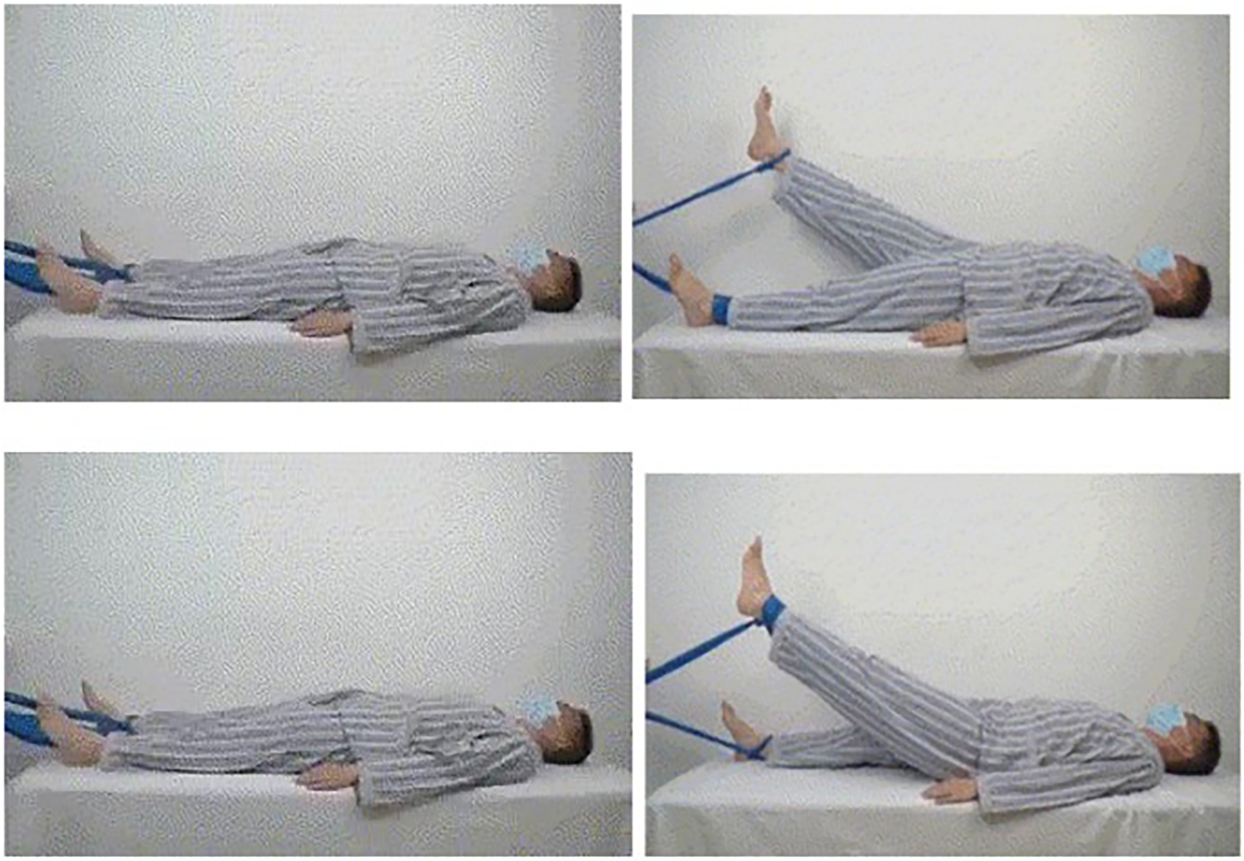

Figure 2. Supine straight-legged raise resistance exercise.

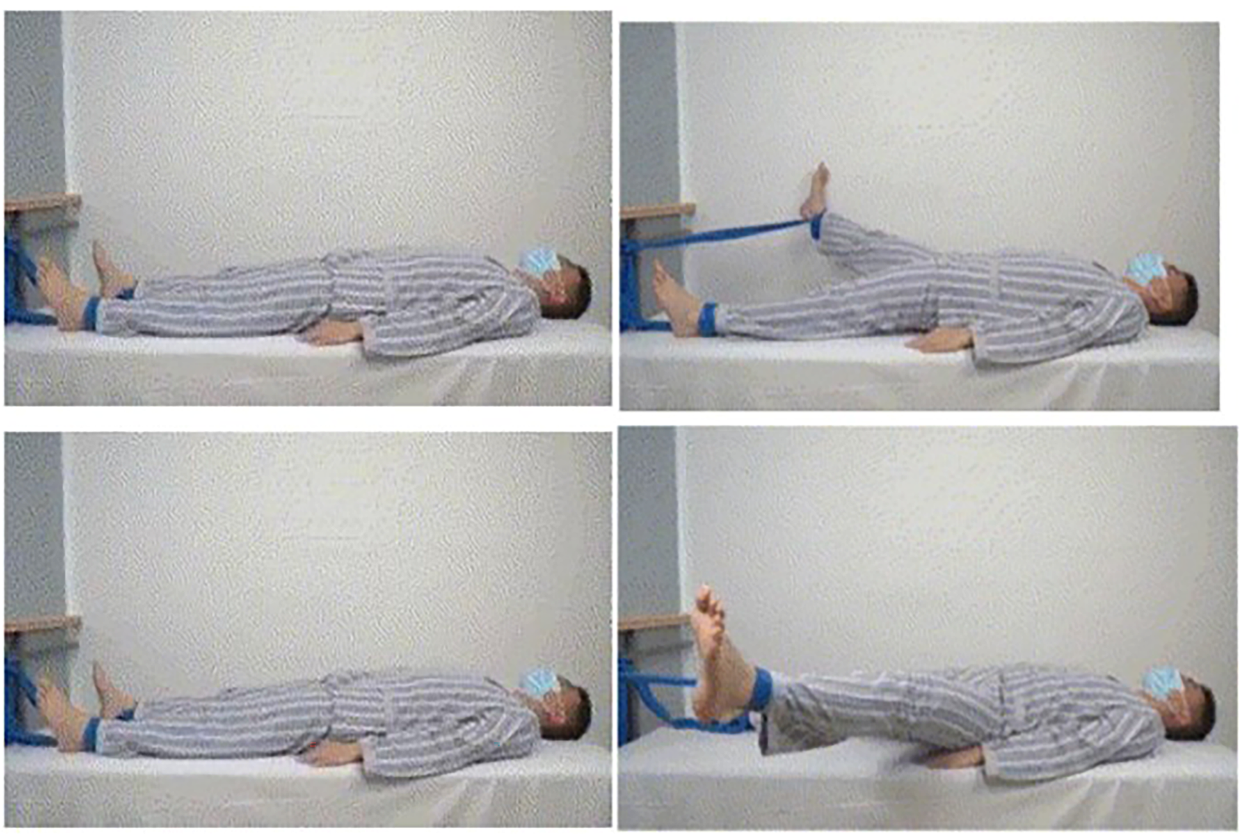

Figure 3. Supine hip abduction resistance exercise.

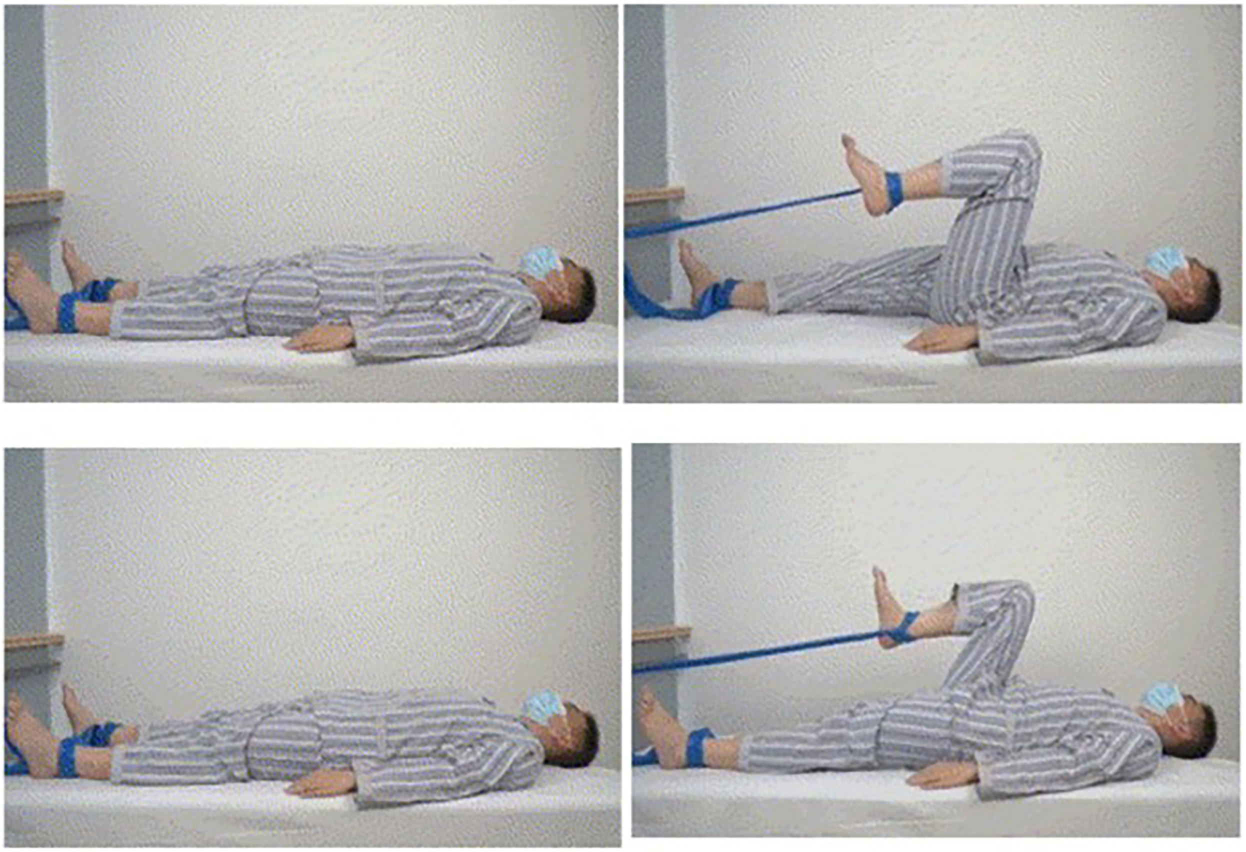

Figure 4. Hip flexion and extension resistance exercise.

were recorded from the time of enrollment until the participant completed the study or withdrew.

Statistical analysis

Data were analyzed using SPSS (version 26.0, SPSS Inc., Chicago, IL, USA) at a significance level of $p < 0.05$. Demographic and clinical characteristics were analyzed using descriptive statistics, mean and standard deviation for normally distributed variables, percentages for categorical variables, and medians and interquartile ranges for non-normally distributed continuous variables.

To examine homogeneity between the two groups, the independent-samples *t*-test and chi-square test were used. Normality was confirmed using the Shapiro–Wilk test. Depending on the data distribution and test assumptions, group differences in clinical and demographic variables were determined using the independent-samples *t*-test, chi-square test, or Mann–Whitney U test.

Results

Study population

From February 2023 to June 2023, 60 patients completed the study, including 30 patients in each group (Figure 5). Of these, two participants (3.3%) in the exercise group withdrew, and no adverse events attributable to the intradialytic exercise were reported. Table 2 presents the demographic and clinical characteristics of the participants, revealing no significant differences in baseline characteristics between the study groups. The majority of patients used a left forearm autogenous arteriovenous fistula for vascular access. Most patients underwent Hemodialysis Filtration (HDF) twice a week and Hemodialysis (HD) once a week.

The 12-week intervention program consisted of 36 sessions. The participation rate was calculated as the proportion of sessions attended by each patient relative to the total number of sessions. After the intervention, the average participation rate for the 28 patients in the intervention group was 94.05% ± 9.09%. Among these patients, 12 (42.86%) completed all intervention sessions. Fifteen patients (53.57%) attended more than 80% of the sessions, whereas only one patient (3.57%) had a participation rate lower than 80% (Table 3).

Assessment of physical and mental function

The results of the physical and mental function assessment are shown in Table 4.

Physical function

After 12 weeks of exercise, the SPPB score was significantly higher in the intervention group ($t = -2.633$, $p = 0.008$), whereas no significant change was recorded in the control

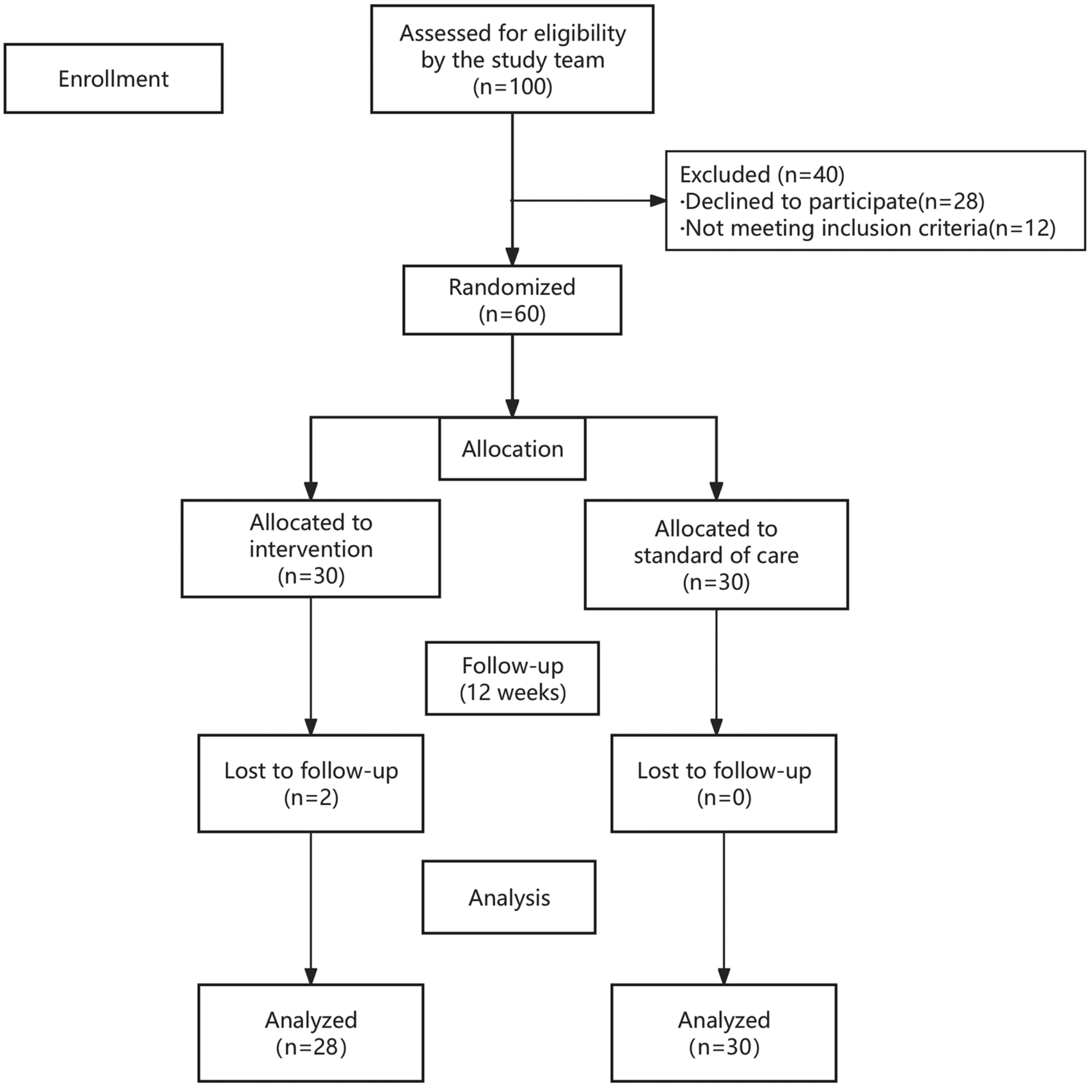

Figure 5. Study flowchart.

group ($t=0.699$, $p=0.485$). The SPPB score was significantly higher in the intervention group than in the control group ($t=-2.320$, $p=0.020$).

Cognitive function

The MoCA score increased significantly after 12 weeks of exercise in the intervention group ($t=-9.257$, $p<0.001$), whereas there was no significant change in the control group ($t=-1.888$, $p=0.069$). The MoCA score was significantly higher in the intervention group than in the control group ($t=5.047$, $p<0.001$).

Fatigue

The FS-14 score was significantly lower after 12 weeks in the intervention group ($t=3.073$, $p=0.005$), whereas no significant change was observed in the control group ($t=0.900$, $p=0.375$). The FS-14 score was significantly lower in the intervention group than in the control group ($t=-2.208$, $p=0.031$).

Sleep quality

The PSQI score significantly decreased after 12 weeks of exercise in the intervention group ($t=6.409$, $p<0.001$), whereas there was no significant change in the control group ($t=0.203$, $p=0.840$). However, there was no statistically significant difference in PSQI scores between the intervention and control groups ($t=-1.279$, $p=0.206$).

Depression

The HAMD score significantly decreased after 12 weeks of exercise in the intervention group ($t=6.523$, $p<0.001$), versus no significant change in the control group ($t=-0.994$, $p=0.328$). The intervention group had a significantly lower HAMD score than the control group ($t=-4.211$, $p<0.001$).

Anxiety

The HAMA score was significantly lower after 12 weeks of exercise in the intervention group ($t=3.634$, $p<0.001$), whereas no significant change was detected in the control

Table 2. Demographics and clinical characteristics data at baseline.

Characteristics	Exercise group ($n=28$)	Control group ($n=30$)	Statistic	p
Age (years)	57.50 ± 11.16	56.10 ± 12.07	0.458	0.649[c]
Male, n (%)	17 (60.7)	20 (66.7)		
Height (m)	1.69 ± 0.87	1.68 ± 0.92	0.268	0.790[c]
Weight (kg)	65.13 ± 12.31	69.42 ± 15.06	−1.147	0.256[c]
Body mass index(kg/m^2)	22.70 ± 3.51	24.41 ± 4.39	−1.623	0.110[c]
Education level, n (%)			2.827	0.406[a]
Primary school or below	2 (7.1)	2 (6.7)		
Junior high school	6 (21.4)	12 (40.0)		
Senior high school	12 (42.9)	8 (26.7)		
University or above	8 (28.6)	8 (26.7)		
Marital status, n (%)			0.238	1.000[b]
Single	3 (10.7)	4 (13.3)		
Married	22 (78.6)	23 (76.7)		
Divorced, or widowed	3 (10.7)	3 (10.0)		
Employment, n (%)	1 (3.6)	6 (20.0)		
Primary disease, n (%)			4.583	0.214[a]
Glomerulonephritis	5 (17.9%)	10 (33.3%)		
Hypertensive renal disease	3 (10.7%)	1 (3.3%)		
Diabetic nephropathy	5 (17.9%)	9 (30.0%)		
Others	15 (53.6%)	10 (33.3%)		
Hemodialysis duration (months)	55.39 ± 43.19	65.23 ± 42.33	−0.876	0.385[c]
Hemoglobin (g/L)	106.38 ± 10.81	110.63 ± 15.80	−1.189	0.239[c]
Albumin (g/L)	38.05 ± 7.13	39.78 ± 2.39	−1.259	0.213[c]
Calcium (mmol/L)	2.33 ± 0.21	2.35 ± 0.22	−0.433	0.667[c]
Phosphorus (mmol/L)	2.00 ± 0.53	2.11 ± 0.42	−0.826	0.412[c]
Serum potassium (mmol/L)	4.78 ± 0.53	4.95 ± 0.81	−0.961	0.341[c]
Parathormone (PTH) (pg/ml)	272.09 ± 205.53	297.95 ± 180.97	−0.509	0.612[c]
Ferritin (ng/ml)	293.54 ± 305.73	246.46 ± 292.01	0.6	0.551[c]
Urea nitrogen (mmol/L)	26.73 ± 6.10	27.13 ± 6.98	−0.233	0.817[c]
Creatinine (µmol/L)	968.24 ± 207.16	1,039.97 ± 308.24	−1.033	0.306[c]
Kt/v	1.28 ± 0.33	1.31 ± 0.35	−0.375	0.709[c]

Note: [a]χ^2 value, [b]Z value, [c]t value.

Table 3. Overview of exercise participation.

	Intervention group ($n=28$)			
Participation rate	100%	90–99%	80–89%	≤80%
Number (%)	12 (42.86%)	10 (35.71%)	5 (17.86%)	1 (3.57%)

group ($t=-1.819$, $p=0.079$). However, there was no statistically significant difference in the HAMA score between the intervention and control groups ($t=-1.866$, $p=0.067$).

Safety, satisfaction, and recommendations

All patients in the intervention group responded well to the elastic band exercise during dialysis, with no major adverse events reported. After 12 weeks of exercise, participants in the intervention group evaluated the exercise modality. Among the 28 study subjects, the satisfaction score was 9.57 ± 0.84, and the recommendation score was 9.71 ± 1.08, indicating high levels of satisfaction and willingness to recommend the exercise regimen (Table 5)

Discussion

The 12-week intradialytic elastic band exercise program conducted in this study provided rehabilitation benefits for patients undergoing MHD, leading to improvements in both physical and mental function. Specific symptoms, including fatigue, poor sleep quality, depression, and anxiety, were significantly improved compared with the pre-intervention levels.

Statistically significant differences were found between the intervention and control groups after 12 weeks, particularly regarding the SPPB, MoCA, FS-14, and HAMD scores. This highlights the positive impact of intradialytic elastic band exercise on somatic and cognitive functions, fatigue, and mood among patients on MHD. However, no significant differences were noted in the PSQI and HAMA scores between the groups, suggesting that the intervention's effects on sleep and anxiety over the 12-week period were limited.

Patients on MHD often experience physical dysfunction, with physical function levels, as defined by leg muscle strength, walking speed, balance, and range of motion, approximately 60–70% of those in healthy individuals without kidney disease [35]. Baseline data illustrated that the SPPB scores of the two groups of patients were 12 and 10.5, indicating a better overall patient condition compared with that in a study by Chen et al. in which most patients had a score higher than 9 points [36].

After 12 weeks of intradialytic elastic band exercise, the intervention group exhibited significant improvement in the SPPB score, particularly in balance function. This suggests that this exercise regimen can notably enhance the physical function of patients on MHD.

The findings of this study are consistent with those of Chen et al. who found that low-intensity strength training during dialysis significantly improves the SPPB score by 21.1%, demonstrating its safety and effectiveness in patients on MHD [36]. Chen et al. enrolled patients in physical poorer conditions, and they included had a longer intervention

Table 4. Summary and comparison of baseline and 12-week data for the exercise and control groups.

		Baseline	12 weeks	t/Z	p
SPPB	Exercise group	12 (9, 12)	12 (10.25, 12)	−2.633	**0.008**
	Control group	10.5 (8, 12)	11 (7.75, 12)	0.699	0.485
Z		−0.597	−2.320		
p		0.550	**0.020**		
MoCA	Exercise group	24.21 ± 3.17	28.36 ± 1.75	−9.257	**<0.001**
	Control group	23.37 ± 4.19	24.37 ± 3.94	−1.888	0.069
t		0.864	5.047		
p		0.391	<0.001		
FS-14	Exercise group	7.64 ± 2.25	5.89 ± 2.60	3.073	**0.005**
	Control group	8.00 ± 2.61	7.47 ± 2.81	0.900	0.375
t		−0.556	−2.208		
p		0.580	**0.031**		
PSQI	Exercise group	12.82 ± 4.10	9.89 ± 4.56	6.409	**<0.001**
	Control group	11.70 ± 4.82	11.60 ± 5.53	0.203	0.840
t		0.952	−1.279		
p		0.345	0.206		
HAMD	Exercise group	9.77 ± 4.37	5.16 ± 2.49	6.523	**<0.001**
	Control group	9.43 ± 5.06	10.32 ± 6.19	−0.994	0.328
t		0.269	−4.211		
p		0.789	**<0.001**		
HAMA	Exercise group	10.61 ± 5.65	7.46 ± 4.81	3.634	**<0.001**
	Control group	8.87 ± 5.76	10.37 ± 6.79	−1.819	0.079
t		1.160	−1.866		
p		0.251	0.067		

Note: Values are presented as the mean ± standard deviation or median (interquartile range). *p*-Values are reported for between-group and within-group comparisons, and significance is indicated by bold font.

Table 5. Satisfaction and recommendation (mean ± standard deviation).

	Exercise group ($n = 28$)
Satisfaction	9.57 ± 0.84

period, leading to more significant outcomes. Similarly, Borja's study indicated that 16 weeks of intradialytic exercise significantly enhanced SPPB scores and physical function in patients on MHD [37].

Resistance training offers several benefits, including improvements of the micro-inflammatory status, oxidative metabolism, and muscle mitochondrial biogenesis [38]. It also increases peripheral tissue blood flow and muscle cell perfusion [39]. A systematic review revealed that resistance training improves physical function regardless of the exercise frequency, intensity, or duration [40]. Exercise programs lasting 8 weeks or longer can significantly enhance physical function for patients on MHD [41]. Zhang et al. demonstrated that progressive resistance training during dialysis improves physical health and quality of life among patients on MHD without causing serious adverse events [42].

Cognitive impairment (CI) is a common but often overlooked complication in patients on MHD [43–45], with prevalence rates ranging from 30% to 70%, which are much higher than those in healthy adults [46]. CI affects various aspects of patients' lives, including adherence to medical prescriptions, decision-making abilities, prognosis, and hospital stay [47]. In this study, the MoCA was employed to evaluate cognitive function. Tiffin-Richards et al. reported that the MoCA reliably identifies cognitive impairment in patients with ESRD undergoing hemodialysis with good sensitivity and specificity [25]. Similarly, Tian et al. found that the MoCA-BJ version has superior sensitivity and specificity in detecting CI among patients on MHD, supporting its use for routine screening in this population [48].

The results of this study demonstrated that cognitive function in the exercise group improved during the intervention period, whereas it remained unchanged in the control group. This finding is consistent with previous research. McAdams-DeMarco et al. found that exercise and cognitive training during dialysis can preserve executive function and mitigate the decline in psychomotor speed in patients on MHD [49]. Similarly, Stringuetta et al. reported that 4 months of aerobic exercise during dialysis improved cognitive function and increased cerebral blood flow in patients on MHD [50]. These cognitive improvements might be attributable to enhanced neuroplasticity, activation of the prefrontal cortex, and increased cerebral blood flow. However, this study differs from some research suggesting that cognitive training and/or physical exercise training only preserve certain cognitive domains, likely because of variations in exercise programs and durations [49,51,52]. More research is needed to confirm these findings.

Patients on MHD often experience significant fatigue, with research indicating that fatigue is a major stressor for this population [53]. Sleep disorders are also common, affecting 23–85% of patients on MHD [54,55]. Additionally, the long-term burden of hemodialysis can lead to psychological issues such as depression and anxiety, which occur at higher rates than in healthy individuals [56,57]. In particular, depression is significantly correlated with increased mortality, especially in patients with cardiovascular diseases [58,59]. This condition both affects mood and interest in daily activities and reduces treatment adherence and worsens prognosis.

After the 12-week intervention with intradialytic elastic band exercises, the FS-14 score was significantly decreased in the intervention group, particularly in the physical fatigue dimension, compared with that in the control group. This suggests that the exercise regimen can significantly alleviate fatigue, likely *via* improvements in physical function.

Sleep disorders represent a common and significant complication among patients undergoing MHD, with previous studies reporting a prevalence range of 23–85% [54,55]. Chronic sleep deprivation and poor sleep quality can reduce daytime vitality, increase fatigue, and elevate inflammatory markers [60]. In severe cases, these disruptions in sleep can adversely affect both cardiovascular and immune system function [61]. In this study, PSQI was employed to evaluate sleep quality. Han et al. found that a PSQI score above 7 in MHD patients was associated with an increased risk of all-cause mortality [62]. The PSQI score was also significantly improved in the intervention group, with notable improvements in sleep quality, sleep duration, sleep efficiency, and daytime dysfunction. This indicates that exercise during dialysis enhances sleep quality and overall daytime function for patients on MHD. Supporting this finding, Cho et al. found that a 12-week exercise program during dialysis significantly reduced sleep fragmentation and improved daily physical activity [63]. Nakamura et al. reported that 6 months of low-intensity exercise during dialysis improved subjective insomnia, although the effect did not persist after 12 months [52], highlighting the need for ongoing exercise to maintain sleep benefits.

Regarding psychological outcomes, the HAMD score was significantly lower in the intervention group than in the control group, indicating improved depression. Although the HAMA score also decreased, the difference between the groups was not statistically significant. Previous research by Ouzouni supports the significant improvement in depression following exercise [64]. Dziubek et al. found that although both resistance and endurance training improved mood in patients on MHD, the improvement in anxiety was more pronounced with endurance training, aligning with our findings [65]. The relief of depression might be linked to increased levels of neurotransmitters such as serotonin and endorphins following exercise [66]. Regular exercise three times a week for 10 weeks was demonstrated to reduce depression in patients on hemodialysis [67], although it remains unclear whether this is attributable to increased interactions with medical staff or improved vitality and confidence. Further research is needed to clarify these mechanisms.

A consensus statement from the Physical Exercise Working Group of the Italian Society of Nephrology indicated that exercise program durations in studies range from 8 weeks to 12 months, with 3-month programs being most common [68]. In this study, a 12-week elastic band exercise program, which was performed three times a week, was implemented for patients undergoing MHD. This duration was beneficial, as it was manageable for patients with busy schedules involving frequent medical appointments and dialysis. The 12-week commitment allowed patients to observe meaningful improvements without being overwhelmed, helping them adhere to the program while experiencing both physical and mental health benefits. Further long-term studies are needed to more conclusively assess the effectiveness of this intervention.

In this study, elastic band exercise was adopted as the intervention during dialysis. Elastic bands are simple, economical, flexible, adjustable, and safe. Patients can adjust the intensity according to their capacity, perform diverse exercises, and select resistance by color and length, streamlining exercise and cutting healthcare costs. During dialysis, with elastic bands as an auxiliary, medical staff can monitor patients' exercise and evaluate and adjust programs promptly under the safety premise, making it highly suitable for patients undergoing.

During the 12-week intradialytic elastic band exercise program, which was performed three times a week, each session was supervised by clinicians. Throughout the process, no adverse reactions were observed, indicating that such exercises during hemodialysis are safe for patients. The intervention was well tolerated with no major adverse events reported, demonstrating the safety of intradialytic elastic band exercises and the high compliance of patients. Moreover, the high satisfaction and recommendation scores given by participants further confirm the feasibility and acceptability of this exercise modality.

This randomized controlled trial had several limitations. First, participants were recruited from a single medical center in Shanghai, potentially limiting the generalizability of the findings. Second, many outcome indicators were based on assessment scales rather than objective data, which might have introduced subjective bias. Third, we did not assess the physical activity levels during the intradialytic periods in either group, which may have influenced the accuracy of the results. Additionally, the sample size was small, and the duration of the exercise intervention was short, preventing the observation of long-term effects. The physical condition of patients on MHD is influenced by various factors such as kidney disease itself, dietary conditions, and the physical state during the intradialytic period, which were not strictly controlled in this study. Furthermore, the lack of blinding could have introduced bias, particularly in the subjective outcomes, such as cognitive function. Larger sample sizes and more objective, long-term intervention studies are needed to further validate our findings.

Conclusions

In conclusion, this study revealed that intradialytic elastic band exercise, characterized by high compliance, safety, effectiveness, and patient satisfaction, can improve both physical and cognitive function, reduce fatigue, and enhance sleep quality while alleviating symptoms of depression and anxiety in patients undergoing MHD. These findings highlight the potential benefits of intradialytic exercise for this patient population. However, given the limitations of this study, further research is needed to confirm and expand upon these results.

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Authors' contributions

CRediT: **Xianxuan Feng**: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Writing – original draft, Writing – review & editing; **Jingwen**

Sun: Investigation, Writing – original draft, Writing – review & editing; **Zihan Wang**: Investigation, Validation, Writing – review & editing, Investigation, Validation, Writing – review & editing; **Nina Zhang**: Investigation, Validation, Writing – review & editing; **Yumei Liu**: Investigation, Validation, Writing – review & editing; **Zhenhong Wang**: Investigation, Validation, Writing – review & editing, Investigation, Validation, Writing – review & editing; **Niansong Wang**: Investigation, Validation, Writing – review & editing; **Guihua Jian**: Investigation, Validation, Writing – review & editing; **Dongsheng Cheng**: Investigation, Validation, Writing – review & editing; **Xiaohua Sheng**: Conceptualization, Formal analysis, Investigation, Methodology, Project administration, Software, Supervision, Validation, Writing – review & editing; **Yanhong Ma**: Conceptualization, Formal analysis, Methodology, Project administration, Software, Supervision, Validation, Writing – review & editing.

Disclosure statement

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Data availability statement

The datasets generated during and analyzed during the present study are available from the corresponding author on reasonable request.

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