International Journal of General Practice Nursing, 2026, Volume 4, Issue 3
https://www.bbwpublisher.com/journal/IJGPN
Online ISSN: 2981-9423
Print ISSN: 2981-9415

Construction and Application of Exercise Intervention Programs during Dialysis for Elderly Maintenance Hemodialysis Patients Based on Multiple Theoretical Models

Yufei Zhao[1], Meimei Rong[1], Ran Hao[1], Wenxiu Liu[2], Meijie Zheng[2], Ziyu Gui[1], Xian Li[3]

[1]College of Nursing and Rehabilitation, North China University of Science and Technology, Tangshan 063210, Hebei, China
[2]Nursing Department, Hebei General Hospital, Shijiazhuang 050000, Hebei, China
[3]Department of Nursing and Medical Development, Hebei General Hospital, Shijiazhuang 050000, Hebei, China

Abstract: *Objective*: To construct a dialysis-based exercise intervention program based on the Multi-Theory Model (MTM) and explore its effects on the physical function and long-term exercise behavior of elderly maintenance hemodialysis patients. *Methods*: Using the convenience sampling method, 70 elderly MHD patients from two tertiary hospitals in Hebei Province from September 2025 to February 2026 were selected as the research subjects. They were divided into the control group and the intervention group according to the dialysis duration, with 35 cases in each group. The control group received routine care, while the intervention group implemented the MTM-based exercise intervention on the basis of routine care for 12 weeks. The physical function (SPPB), 6-minute walking distance, lower limb muscle strength, exercise self-efficacy, and exercise compliance of the two groups were compared before the intervention and at 4,8, and 12weeks of the intervention. *Results*: After the intervention, the SPPB score, 6-minute walking distance, lower limb muscle strength, exercise self-efficacy, and exercise compliance of the intervention group were all better than those of the control group, and all indicators continued to improve with the extension of the intervention time, and the differences were statistically significant ($P < 0.05$). *Conclusion*: The MTM-based exercise intervention during dialysis can effectively improve the physical function, muscle strength, and exercise endurance of elderly MHD patients, as well as enhance exercise self-efficacy and exercise compliance, which is conducive to promoting the formation of long-term exercise behavior in patients and can provide new intervention ideas for the exercise rehabilitation and long-term behavior management of elderly hemodialysis patients.

Keywords: Multiple theoretical models; Elderly; Maintenance hemodialysis; Physiological functions; Lower limb muscle strength; Exercise endurance

Online publication: August 31, 2026

1. Introduction

Maintenance hemodialysis (MHD) refers to the situation where patients receive continuous and regular hemodialysis treatment for more than 3 months [1]. Data from the Chinese National Renal Data System (CNRDS) shows that there are over 1.06 million dialysis patients in China, among whom 91.6% are hemodialysis patients [2]. Long-term uremic state and dialysis treatment can lead to complications such as anemia, muscle atrophy, and osteoporosis, which can result in decreased exercise endurance, reduced muscle strength, and impaired daily living activities [3]. Long-term lack of physical activity can further accelerate the deterioration of physical function [4]. Studies have shown that the exercise capacity of MHD patients is only 50% to 60% of that of healthy individuals [5]. Currently, exercise intervention has been proven to be able to improve the physical function and exercise endurance of MHD patients. However, existing studies mostly focus on exercise methods and short-term effect evaluation [6–8]. Insufficient attention has been paid to maintaining patients' long-term exercise behavior. Especially for elderly MHD patients, due to long-term disease burden, fatigue state, and concerns about exercise risks, they generally have low exercise compliance and difficulty in long-term persistence [9]. Therefore, how to promote the formation of patients' long-term exercise behavior has become an important issue in the field of dialysis rehabilitation. The multi-theory model (MTM) is a health promotion theory centered on behavior change, emphasizing the promotion of the continuous formation of healthy behaviors through "behavior initiation" and "behavior maintenance" [10]. It has good application value in the long-term behavior management of chronic diseases. However, the application of MTM-based exercise intervention in elderly MHD patients is still rare. Based on this, this study innovatively applies MTM to the entire process of exercise management in the dialysis of elderly MHD patients, constructing a dialysis-based exercise intervention model integrating exercise training, behavior reinforcement, and continuous support, and exploring its effects on patients' physical function, muscle strength, exercise endurance, exercise self-efficacy, and exercise compliance, in order to provide new theoretical basis and practical references for the long-term exercise rehabilitation management of elderly MHD patients.

2. Construction of the exercise intervention plan for maintenance hemodialysis patients

2.1. Establishment of the research team

The research team consists of 9 members, with the following divisions of labor: 1 mentor (graduate student) is responsible for finalizing the intervention plan; 1 exercise rehabilitation physician is responsible for assessing the patient's physical condition and reviewing the plan content; 2 hemodialysis room physicians jointly review the exercise plan and handle adverse events during dialysis; 2 researchers are responsible for literature review, expert consultation implementation, data collection, plan design, and on-site execution, and assist nurses in completing the exercise intervention; 1 hemodialysis room nurse manager supervises the implementation of the plan; 2 hemodialysis nurses are specifically responsible for the operation implementation of the intervention plan.

2.2. Formulation of the exercise intervention plan for maintenance hemodialysis patients

2.2.1. Drafting the initial plan

According to the "6S" evidence model, systematic searches were conducted in domestic and foreign databases such as CNKI, China Biomedical Literature Database, VIP, Wanfang Data Knowledge Service Platform, Web of Science, Science Direct, Cochrane, PubMed, Embase, etc. The Chinese search terms were: “hemodialysis,” “renal dialysis,” “maintenance hemodialysis,” “elderly maintenance hemodialysis,” “multiple theory model,” “rehabilitation,” “exercise intervention,” “physical function,” “body function,” “physical function,” etc. The search time range was set from the establishment of each database to June 2025. After screening, a total of 12 relevant articles were included [11–22]. The research team used the multiple theory model as the theoretical framework, completed the quality evaluation and evidence content extraction of the included literature, and initially drafted the intervention plan.

2.2.2. Expert consultation

A total of 15 experts from tertiary grade A hospitals and universities in Beijing, Tianjin, etc. were selected. Inclusion criteria: (1) Clinical or management position in cardiovascular internal medicine for ≥10years; (2) Bachelor’s degree or above, intermediate or above professional title; among them, 11 were female and 4 were male; age 42 to 62 years, average (52.33±6.77) years; working years 20 to 41 years, average (30.46±6.77) years; professional fields: 4 in nephrology nursing, 5 in hemodialysis nursing, 5 in geriatric nursing, 1 exercise rehabilitationist. All experts gave informed consent and voluntarily participated in this study. The first round of expert consultation was sent out in the form of an email questionnaire in July 2025, and all 15 questionnaires were recovered, with a recovery rate of 100%. Based on the feedback from the experts, the questionnaire was revised, and the second round of expert consultation was initiated in August of the same year, with a total of 15 questionnaires sent out and 13 recovered, a recovery rate of 86.7%. The expert authority coefficients of the two rounds of inquiries were 0.85 and 0.86, respectively, indicating that the expert opinions were highly reliable. The coefficient of variation for each item fluctuated between 0 and 0.14. The Kendall’s coefficient of agreement for the two rounds was 0.224 and 0.305, respectively, suggesting that the consistency of expert ratings in the two rounds reached a statistically significant level, and the consistency in the second round was higher than that in the first round. Based on the experts’ ratings and suggestions, the intervention plan was further optimized, and a final draft version was formed.

2.2.3. Pre-experiment

According to the established inclusion and exclusion criteria, a total of 10 elderly patients undergoing maintenance hemodialysis (including 5 in the control group and 5 in the intervention group) were included. A 4-week pre-experiment was conducted. After the pre-experiment, interviews were conducted with the above patients to obtain their actual experiences and subjective feedback. The interview outline covered the following contents: (1) The specific mastery level of the patients regarding the knowledge and operation methods related to exercise during dialysis, as well as the aspects that they were still not proficient in; (2) Whether they could complete the training according to the current plan and provide specific improvement suggestions or adjustment recommendations for the plan; (3) The family and medical support they felt and their expectations.

Based on the interview results, the plan was optimized, and a final draft version of the exercise intervention plan was formed.

2.2.4. Implementation of the intervention plan

(1) Training and assessment: Before the implementation of the intervention measures, the doctors and

head nurses of the hemodialysis unit conducted a one-week systematic training for the team members. The specific training contents included basic theoretical knowledge, operational procedures, safety monitoring points, questionnaire completion, result index assessment methods, and emergency response strategies. After the training, theoretical and operational assessments were conducted to ensure that all operations met the standards.

(2) Project implementation: Exercises were arranged to be conducted 30 minutes to 2 hours after each dialysis treatment, but the limbs connected to the catheters did not participate in any exercises. The exercise frequency was three times per week, and the intervention lasted for 12 weeks. After the patients were enrolled, the team members were responsible for explaining relevant exercise knowledge and providing action guidance; the rehabilitation therapist evaluated the patient's physical condition based on the patient's physical function status, and accordingly formulated the exercise mode and gradually increased the duration and intensity of the exercise. The established plan must be strictly followed throughout the implementation process, and corresponding records must be made.

3. Application of the exercise intervention plan for maintenance hemodialysis patients

3.1. Research subjects

Using the convenience sampling method, elderly patients undergoing maintenance hemodialysis in two tertiary grade A hospitals in Hebei Province from September 2025 to February 2026 were selected as research subjects.

3.1.1. Inclusion criteria

(1) Conforming to the diagnostic criteria for end-stage renal disease stipulated in the "Guidelines for Early Screening, Diagnosis and Prevention of Chronic Kidney Disease," receiving maintenance hemodialysis ≥3times per week, and undergoing dialysis treatment for≥3months [23];
(2) Age≥60years old;
(3) Muscle strength≥3levels, without limb disability;
(4) Conscious and able to communicate normally;
(5) Providing informed consent and voluntarily participating in this study.

3.1.2. Exclusion criteria

(1) Patients with severe complications, such as heart failure, malignant tumors;
(2) Patients with severe lower limb thrombosis, spinal or joint diseases that prevent movement;
(3) Severe renal osteopathy;
(4) Lower limb catheterization.

3.1.3. Withdrawal and dropout criteria

(1) Patients requiring hospitalization due to disease changes;
(2) Patients unable to adhere to the exercise plan;
(3) Patients who died during the study period.

Sample size estimation was based on the formula for comparing two sample means n1 = n2 = 2[(u + u) σ/δ], with a two-sided α =0.05 and β = 0.10. From the table, u = 1.96 and u = 1.28. Using the simple physical function score as the main outcome indicator, 10 patients (5 in each group) were selected for a pre-test. Based on the pre-test results, the simple physical function score of the intervention group was (7.80 ± 1.48) points, and that of the control group was (6.40±2.07) points. Based on this, the overall standard deviation σ=1.7, and the mean difference δ=1.4 were estimated. Substituting into the formula, n1=n2=31.Considering a 10% dropout rate, at least 68 cases were required for both groups. This study actually included 70 cases, with those receiving dialysis on Mondays, Wednesdays, and Fridays set as the control group (35 cases), and those on Tuesdays, Thursdays, and Saturdays set as the intervention group (35 cases). All patients completed the entire study. This study has been approved by the hospital ethics committee (approval number: 2025 Scientific Ethics Review No.466), and all participants have signed informed consent forms.

3.2. Intervention methods

3.2.1. Intervention method for the control group

The control group received routine care.

(1) The duration of the group health education was set between 20 and 30 minutes. After the patients were enrolled, the responsible nurse would give a group lecture, instructing the patients to perform aerobic and resistance exercises within 30 minutes after dialysis. Each session involved cycling on the bed for 10 to 15 minutes, and the exercise intensity was determined based on the Rating of Perceived Exertion (RPE) at 11 to 13 points [24]. The exercises were conducted three times a week. At the same time, the nurse would explain the basic knowledge of end-stage renal disease, hemodialysis, treatment principles, vascular access maintenance, identification of common complications, and nursing methods.

(2) In terms of dialysis care, before dialysis, the patient's physiological condition would be assessed, precautions would be informed, and preparations would be assisted. During the dialysis process, health education would be strengthened, vascular access protection would be ensured, the machine would be kept running properly, and dialysis adequacy would be guaranteed. After the dialysis, the patient's vital signs, fluid output, weight, and disconnection time would be recorded.

(3) Dietary care required the patient to follow a high-quality, high-protein, low-potassium, and low-sodium diet plan, and to strictly control weight and fluid intake.

(4) Routine follow-up was conducted according to the department's standards through regular phone or outpatient follow-up, with the aim of answering patients' questions, but no additional systematic exercise guidance was provided.

3.2.2. Intervention method for the experimental group

The experimental group received the intervention measures of the control group in addition to the intervention plan for maintenance hemodialysis patients based on multiple theoretical models, as detailed in **Table 1**.

Table 1. Exercise intervention scheme for elderly patients on maintenance hemodialysis

Intervention	Intervention time	Intervention content
Participatory conversation	After being enrolled: Discuss for 30 minutes	1. Promotion of health knowledge: Discuss the benefits of the two-way communication exercise for MHD patients, explore the drawbacks of long-term lack of exercise and movement disorders, analyze the current difficulties, and discuss the corresponding solutions. 2. Explain the exercise manual (including knowledge, duration, frequency, and precautions regarding exercise during dialysis).
Behavioral confidence	After being enrolled: Discuss and practice for 30 minutes	1. Expert lectures and nurse skill practice: Explain the movement techniques and key points. 2. Sharing success stories: Share in the group the successful cases where exercise improved physical functions, muscle strength, and quality of life. Regularly share relevant knowledge about blood dialysis exercises and prevention of complications to enhance self-confidence. 3. Understanding and familiarizing with the goals and plans of exercise during dialysis: Follow the principle of "gradual progress," break down complex exercises into simple steps, and each movement can be repeated 8 to 10 times.The exercises mainly include:(1) warm-up exercises; (2) resistance exercises; (3) intermittent rest; (4) aerobic exercises; (5) stretching exercises;
Change in physical environment	The entire intervention process	1. Fitness equipment: Provide equipment such as resistance bands and bed-mounted exercise bikes, and offer guidance on their use. 2.WeChat Sports: Enable the WeChat Sports function, conduct daily step count statistics, organize WeChat group step challenges, and reward those who perform well.
Emotional transformation	The entire intervention process	1. Proactively inquire about the patient's fear of exercise (informing the patient that "most patients have similar feelings when they first start exercising, and through gradual exercise, they feel the benefits of exercise and gradually become familiar with the intensity and frequency of exercise; their feelings will gradually improve"); 2. Encourage positive feedback from warm-up through safety demonstrations; Using cognitive restructuring techniques (such as changing "I can't do it" to "I currently lack strength, but can gradually increase") to help patients establish positive emotions.
Practice of behavioral change	Set up an exercise plan and goals:	Early stage (1-4 weeks):30 minutes (1) Warm-up exercise (RPE<10, 5min): Except for the arm on the puncture side, all joints should be moved: wrist, elbow, shoulder, knee, hip, deep breathing and relaxation for 5 times; (2) Resistance exercise (RPE11~12,8min): Knee joint flexion and extension resistance exercise: Participants slowly bend and extend the knee joint, keep the foot on the bed, bend the knee about 90 degrees, and then straighten the leg and place it flat on the bed; Supine straight leg lifting resistance exercise: Participants straighten their knee joints, lift their legs off the bed, feel resistance, and then slowly lower them; (3) Intermittent rest (3 minutes): abdominal breathing or relaxation training (4) Aerobic exercise (RPE11~12,8min) on a bed bike: relax the neck, tighten the abdomen, keep the upper body still, and slowly take deep breaths throughout the exercise; Assist patients in placing themselves in a comfortable lying position, with their feet naturally relaxed and ready to be placed on the pedals. Start applying force clockwise, gradually increasing the speed; (5) Stretching exercise (RPE<10,5min): Neck stretching: Move the head closer to the left and right shoulders and feel the muscles on both sides of the neck being stretched; Arm extension: Extend the arm, fix the shoulder joint, and bend and straighten the elbow; Shoulder shrugging rotation: Lift the shoulders up and rotate around the shoulder joint; Chest and upper back extension: The patient lies on the right side and stretches the left upper limb backwards, feeling the chest muscles being stretched and the back muscles being stretched. Switch to the other side; Mid-term (5-8 weeks):35 min (1) Warm-up exercise: Same as above (2) Resistance exercise (RPE12-13,11min): Increase on the basis of 1-4 weeks, supine hip abduction resistance exercise: Participants straighten their knee joints, lift their legs off the bed, and abduct their hip joints by opening them outward until resistance is felt, then restore

Practice of behavioral change	Set up an exercise plan and goals:	the knee joints to their starting position; (3) Intermittent rest: Same as above (4) Aerobic exercise (RPE12-13,11 min): Bedtime cycling. (5) Stretching exercise: Same as above Late stage (9-12 weeks):40 minutes (1) Warm-up exercise: Same as above (2) Resistance exercise (RPE13-14,14min): Increase on the basis of mid-term exercise. Hip joint flexion and extension resistance exercise: Participants bend their knees and hip joints, lift their feet off the bed, and bend the hip joint towards the abdomen until resistance is felt, and the knee joint returns to the starting position. (3) Intermittent rest: Same as above (4) Aerobic exercise (RPE12-13, 14 min): Bedtime cycling. (5) Stretching exercise: Same as above
Practice of behavioral change	Set up an exercise plan and goals:	Notes: 1. Exercise taboos: The arm with a catheter pathway should not participate in resistance and aerobic exercise. 2. Exercise frequency: Three times a week, scheduled on dialysis days. Each exercise consists of at least one set of 20 to 30 repetitions, while maintaining the intensity of the exercise within a subjective perceived fatigue level of 11 to 13 points 3. Safety monitoring: ask about their physical condition before exercising; measure blood pressure, heart rate, and blood sugar for patients with diabetes. During exercise, monitor blood pressure and heart rate every 20 minutes to keep them within the maximum reserve heart rate range of ≤70% to 80%, with an RPE score of≤15 points. Also, pay attention to discomfort symptoms such as chest pain and dizziness, and ensure the safety of the puncture site and tubing. After exercise, observe the patient's condition, record blood pressure and heart rate, and any discomfort symptoms. 4. Stop indicators: If any of the following conditions occur, immediately stop the operation: chest, arm, neck, or jaw pain or compression, severe chest tightness, shortness of breath, headache, dizziness, fainting, fatigue, severe arrhythmia, unbearable muscle spasms or joint pain, blood pressure above 220/105mmHg. For patients with hypertension, dialysis catheter detachment, bleeding, or machine failure.
Change in the social environment	The entire intervention process	1. Medical support: Provide patients with corresponding guidance during the intervention process. After the intervention, a weekly phone follow-up will be conducted in the first month, and a biweekly follow-up will be conducted in the second month. 2. Peer support: Establish mutual aid groups through WeChat groups, allowing patients to communicate and interact with each other, thereby achieving the goal of common learning. 3. Family support: Provide psychological support to boost confidence, allowing family members to participate in suitable activities such as walking and Tai Chi together.

3.3. Evaluation tools

3.3.1. Simple Physical Performance Battery (SPPB)

The Simple Physical Performance Battery (Short Physical Performance Battery, SPPB) is a commonly used tool for assessing overall physical function [25]. It consists of three parts: balance test, walking speed measurement, and five sit-to-stand tests. In the balance test, the duration of each of the three postures (toes together, half-parallel standing, parallel standing) that the subject maintains is recorded. The walking speed test requires the subject to walk as fast as possible for 4 meters, with two measurements taken, and the shorter time is used as the scoring basis. The five sitting-to-standing tests include the subject crossing their hands in front of their chest and performing five "stand-up — sit-down" movements as quickly as possible, with the time taken recorded. The scoring range for each test is 0 to 4 points, and the total score ranges from 0 to 12 points. The higher the score, the better the physical function. The scores are classified into grades based on the total score: 0 to 6 points indicate poor physical function, to 9 points indicate a medium level, and 10 to 12 points indicate good physical function.

3.3.2. 6-Minute Walk test (6MWT)

The 6-Minute Walk test (6-Minute Walk test, 6MWT) is an objective measurement indicator used to assess the patient's exercise endurance [26]. During the test, the subject walks along a 30-meter straight corridor, and the maximum distance they can walk in 6 minutes is recorded. The walking distance is divided into four grades: Grade 1 is less than 300 meters, Grade 2 is between 300 and 374 meters, Grade 3 is between 375 and 449 meters, and Grade 4 is 450 meters or more. A shorter walking distance indicates poor exercise endurance.

3.3.3. Lower limb muscle strength

The Five-times-sit-to-stand test (Five-times-sit-to-stand test, FTSST) is used to assess the lower limb muscle strength of the elderly [27]. During the test, the subject sits on a chair about 43 centimeters high without armrests, with hands crossed in front of the chest, back straight, and feet flat on the ground. The subject needs to complete 5 consecutive "stand-up—sit-down" actions as quickly as possible, with each measurement repeated 3 times, and the average value is taken as the final result.

3.3.4. Exercise self-efficacy

Exercise Self-Efficacy Scale (Exercise Self-Efficacy Scale, ESE) is used to assess and measure the confidence level of patients in adhering to exercise [28]. This scale was originally developed by Bandura and later translated into Chinese by Tung et al. and adapted for cross-cultural use. The scale contains 18 items and uses the Likert 3-point rating method, with options including "completely confident," "half confident," and "completely unconfident." The total score is calculated by adding the scores of each item, dividing by 18, and then multiplying by 100%. If the score is below 50 points on a 100-point scale, it indicates low self-efficacy; the higher the score, the stronger the patient's confidence in exercise. This scale has been validated in the chronic disease patient population and shows good reliability and validity, with a Cronbach's alpha coefficient of 0.966.

3.3.5. Exercise compliance scale

The exercise compliance questionnaire developed by Li Xue et al. was used for assessment [29]. This tool consists of 3 dimensions and a total of 12 items: physical exercise compliance 6 items, exercise monitoring compliance 3 items, and active seeking advice compliance 3 items. The scoring is based on a 4-point rating system (ranging from 1 to 4 points), with corresponding scores for each option as follows: "completely unable to do" is 1 point, "occasionally able to do" is 2 points, "basically able to do" is 3 points, and "completely able to do" is 4 points. The total score of the questionnaire ranges from 12 to 48. The higher the score, the better the patient's exercise compliance. The Cronbach's α coefficient of this scale is 0.87.

3.4. Data collection and quality control methods

In this study, data collection was conducted at four time points: before the intervention began, 4 weeks after the intervention, 8 weeks after the intervention, and 12 weeks after the intervention. All assessments were completed by the research team members within 20 minutes after each hemodialysis treatment of the patients. Before the formal data collection began, all members involved in data collection were uniformly trained, and it was required that the two assessors maintain consistent measurement results for the same research subject at the same time point.

3.5. Statistical methods

Data analysis was completed using SPSS 29.0 software. For continuous variables that followed a normal distribution, they were described by the mean ± standard deviation ($\overline{x}$ ± s), and the comparison between groups was conducted using the independent-samples *t*-test; for continuous variables that did not follow a normal distribution, they were expressed by the median (interquartile range) [M(P25, P75)], and the comparison between groups was performed using the Mann-Whitney U test. Categorical variables were described by frequency and percentage, and the differences between groups were analyzed using the x^2 test, Fisher's exact probability method, or rank sum test. For comparisons between groups at different time points, repeated measures analysis of variance or generalized estimating equations were selected based on the characteristics of the data distribution. The significance level of the test was set at α= 0.05, and any *P* value less than 0.05 was considered statistically significant.

4. Results

4.1. Comparison of general data between the two groups

The comparison of general data between the two groups is shown in **Table 2**.

Table 2. Baseline comparison of 2 groups before intervention

Variable		Control group (*n*=35)	Intervention group (*n*=35)	Statistic	*P* value
Age (years, $\overline{x}$ ± s)		72.23±3.200	72.06±2.700	0.242[1)]	0.809
Gender [Example (Percentage, %)]	Man	20	21	0.059[2)]	0.808
	Woman	15	14		
BMI (kg/m2, $\overline{x}$ ± s)		23.50±2.890	23.75±3.759	− 0.309[1)]	0.759
Smoking [Example, (percentage, %)]	Yes	7	9	0.324[2)]	0.569
	No	28	26		
Drinking alcohol [Example, (percentage, %)]	Yes	12	6	2.692[2)]	0.101
	No	23	29		
Educational attainment [Example (percentage, %)]	Primary school and below	17	17	− 0.285[3)]	0.776
	Middle school	11	8		
	High school or vocational school	4	7		
	University or above	3	3		
Living situation [example (percentage, %)]	Living with spouse and children	7	11	2.157[4)]	0.556
	Living with children	11	11		
	Living with spouse	14	9		
	Living alone	3	4		
Medical payment [example (percentage, %)]	Provincial medical insurance	12	10	0.527[4)]	0.896
	City medical insurance	22	24		
	Self-payment	1	1		

Variable		Control group (n=35)	Intervention group (n=35)	Statistic	P value
Occupation [example (percentage, %)]	Employed	6	7	$0.007^{3)}$	0.995
	Retired	22	20		
	Unemployed	7	8		
Dialysis duration (months, $\bar{x} \pm s$)		38.77±13.975	35.00±16.803	$1.021^{1)}$	0.311
Primary disease [example (percentage, %)]	Kidney disease	16	19	$0.886^{4)}$	0.959
	diabetes	9	8		
	hypertension	3	3		
	Polycystic kidney	4	3		
	Kidney stones	3	2		
Complications [Examples (percentage, %)]	≥3types	28	24	$1.197^{2)}$	0.274
	<3types	7	11		

Note: 1) t value; 2) x^2 value; 3) Z value; 4) Fisher's exact probability method.

4.2. Comparison of simple physical function scores at different time points between the two groups

Table 3 shows the comparison of simple physical function scores at different time points between the two groups.

Table 3. Comparison of simple physical function scores at different times between the two groups

Group	Sample	Baseline	4 weeks of intervention	8 weeks of intervention	12 weeks of intervention
Control group	35	6.00 (5.00, 7.00)	7.00 (6.00, 8.00)	7.00 (6.00, 9.00)	8.00 (7.00,9.00)
Intervention group	35	7.00 (6.00, 8.00)	8.00 (7.00, 9.00)	9.00 (8.00, 9.00)	9.00 (9.00,10.00)
Z value		2.251	2.337	3.770	4.693
P value		0.024	0.019	<0.001	<0.001

Note: Wald $x^2_{\text{between groups}}$=63.000, Wald x^2_{time}=171.614, Wald $x^2_{\text{interaction}}$=8.211, all P<0.05.

4.3. Comparison of 6-minute walking test distances between two groups at different times

Table 4 shows the comparison of 6-minute walking test distances between two groups at different times.

Table 4. Comparison of 6-minute walking test results between the two groups at different times

Group	Sample	Baseline	4 weeks of intervention	8 weeks of intervention	12 weeks of intervention
Control group	35	334.23±13.23	334.89±13.14	335.37±13.38	336.66±14.07
Intervention group	35	336.11±12.22	340.63±12.65	344.97±12.69	349.09±12.74
t value		-0.619	-1.862	-3.080	-3.873
P value		0.538	0.067	0.003	<0.001

Note: F_{time}=147.726, F_{group}=5.799, $F_{\text{interaction}}$=71.769, P_{time}=<0.001, P_{group}=<0.019, $P_{\text{interaction}}$=<0.001.

4.4. Comparison of lower limb muscle strength between two groups at different times

Table 5 shows the comparison of 6-minute walking test distances between two groups at different times.

Table 5. Comparison of lower limb muscle strength at different times between the two groups

Group	Sample	Baseline	4 weeks of intervention	8 weeks of intervention	12 weeks of intervention
Control group	35	16.84±1.66	17.08±1.34	17.15±0.60	17.71±0.75
Intervention group	35	17.37±0.92	18.62±0.93	19.78±0.88	20.95±0.98
t value		-1.666	-5.548	-14.566	-15.435
P value		0.102	<0.001	<0.001	<0.001

Note: F_{time}=68.726, F_{group}=155.551, F-$_{interaction}$=27.469, P_{time}=<0.001, P_{group}=<0.001, $P_{interaction}$=<0.001.

4.5. Comparison of self-efficacy scores for exercise at different times between two groups

Table 6 shows the comparison of self-efficacy scores for exercise at different times between two groups.

Table 6. Comparison of self-efficacy scores for exercise at different times between the two groups

Group	Sample	Baseline	4 weeks of intervention	8 weeks of intervention	12 weeks of intervention
Control group	35	54.76 (50.00, 58.33)	55.63 (52.77, 61.11)	56.82 (52.77, 58.33)	57.93 (52.77, 58.33)
Intervention group	35	58.41 (55.55, 63.88)	62.06 (55.55, 69.44)	66.10 (61.11, 69.44)	70.47 (63.88, 75.00)
Z value		1.104	2.265	5.068	5.822
P value		0.269	0.024	<0.001	<0.001

Note: Wald $x^2_{between\ groups}$=47.490, Wald x^2_{time}=32.987 Wald $x^2_{interaction}$=10.966, all P<0.05.

4.6. Comparison of exercise compliance scores between two groups at different times

Table 7 shows the comparison of exercise compliance scores between two groups at different times.

Table 7. Comparison of movement compliance scores at different times between the two groups

Group	Sample	Baseline	4 weeks of intervention	8 weeks of intervention	12 weeks of intervention
Control group	35	24.00 (23.00, 25.00)	25.00 (24.00, 27.00)	26.00 (26.00, 27.00)	27.00 (27.00, 28.00)
Intervention group	35	24.00 (24.00, 26.00)	28.00 (28.00, 29.00)	31.00 (31.00, 32.00)	33.00 (33.00, 34.00)
Z value		0.132	5.257	6.746	6.481
P value		0.895	<0.001	<0.001	<0.001

Note: Wald $x^2_{between\ groups}$=186.513, Wald x^2_{time}=401.756, Wald $x^2_{interaction}$=91.330, all P<0.05.

5. Discussion

5.1. Exercise intervention can improve the physical function of elderly maintenance hemodialysis patients

Elderly MHD patients often suffer from complications such as anemia, muscle atrophy, and osteoporosis due to long-term uremia and dialysis treatment, resulting in decreased exercise endurance, muscle weakness, and limitations in daily activities. Long-term lack of physical activity will further accelerate the deterioration of physical function [30–31]. The results of this study show that after 12 weeks of exercise intervention during dialysis, the SPPB score of the intervention group improved significantly compared to the control group, and the improvement trend became more obvious as the intervention time increased, suggesting that exercise intervention during dialysis can effectively improve the physical function of elderly MHD patients. This result is consistent with that of Jofré-Saldía E et al. [32]. Analyzing the reasons, regular exercise training can increase the patient's physical activity level, improve lower limb stability, and enhance daily activity ability. This study adopts an aerobic exercise combined with resistance exercise mode during dialysis, and gradually increases the exercise time and intensity according to the patient's tolerance, which helps the patient gradually establish exercise adaptability and thereby improve overall physical function. Different from previous studies that mainly focused on exercise methods and training intensity, this study innovatively introduces the multi-theoretical model (MTM) into the exercise management of elderly MHD patients during dialysis. It not only focuses on short-term improvement of physical function but also emphasizes the establishment and long-term maintenance of exercise behavior. By integrating behavioral change strategies such as behavior initiation, behavior maintenance, social support, and continuous follow-up into the entire process of exercise during dialysis, this study constructs a comprehensive intervention model combining "functional training + behavior management," breaking through the limitation of traditional exercise intervention in dialysis that only emphasizes the exercise prescription itself. The results suggest that the exercise management model based on multiple theoretical models is more in line with the long-term rehabilitation characteristics and chronic disease management needs of elderly hemodialysis patients. Therefore, this study not only verifies the effectiveness of exercise intervention during dialysis in improving the physical function of elderly MHD patients, but also further explores the application value of behavioral theory in exercise management during dialysis, providing a new theoretical basis and practical references for the long-term rehabilitation care of elderly MHD patients.

5.2. Exercise intervention can improve the muscle strength and exercise endurance of elderly maintenance hemodialysis patients.

Long-term uremia can lead to toxin accumulation, chronic micro-inflammatory response, and protein-energy consumption. At the same time, the patient's daily activity volume decreases, and progressive muscle atrophy and decline in cardiopulmonary function occur, which in turn leads to decreased lower limb muscle strength and shortened 6-minute walking distance, increasing the risk of falls and functional impairment. The results of this study show that after 12 weeks of exercise intervention, the lower limb muscle strength and 6-minute walking distance of the intervention group were significantly improved compared to the control group, and the improvement effect became more significant as the intervention time increased, suggesting that exercise intervention during dialysis can continuously improve the muscle strength and exercise endurance of elderly MHD patients. This result is consistent with that of Bae YH et al. [33]. The mechanism may be related to the synergistic effect of aerobic exercise combined with resistance exercise. This study adopts a phased progressive exercise plan and regularly conducts bed cycling training and lower limb resistance training during dialysis. Aerobic exercise can improve cardiopulmonary endurance and oxygen metabolism levels, while resistance exercise helps to enhance lower limb muscle strength, delay muscle function deterioration, and, at the same time, stretching and relaxation training before and after exercise can improve exercise tolerance and reduce the risk of exercise injury. Existing studies have shown that regular aerobic exercise can increase 6-minute walking distance and improve physical function [34]. In addition, this study innovatively adopts individualized and progressive exercise training strategies for elderly MHD patients, adjusting the exercise time and intensity dynamically according to the patient's tolerance, making the exercise plan more in line with the physiological characteristics and rehabilitation needs of elderly patients. This combined model of "dialysis treatment—exercise training—functional recovery" helps improve the safety of patients' exercise and their long-term participation rate. It embodies the concept of precise exercise rehabilitation management for elderly dialysis patients and has good clinical promotion value.

5.3. Exercise intervention can improve the exercise self-efficacy and exercise compliance of elderly maintenance hemodialysis patients.

Due to the long-term disease burden, continuous fatigue, and decreased activity ability of elderly hemodialysis patients, they often have concerns about the safety of exercise and lack the confidence and motivation to continuously participate in exercise, which leads to low exercise compliance [35]. The results of this study show that the exercise intervention based on multiple theoretical models during dialysis can effectively improve the exercise self-efficacy and exercise compliance of patients, and the improvement effect becomes more obvious with the extension of intervention time. This result is consistent with the research results of Liu Yibing et al. [36]. The study believes that the mechanism may be related to the dual structure of "behavior initiation" and "behavior maintenance" in the multiple theoretical models. In the behavior initiation stage, through health education, exercise risk cognition intervention, and professional guidance, the patients' understanding of the safety of exercise during dialysis and the health benefits is enhanced, and the confidence in exercise behavior is strengthened; in the behavior maintenance stage, measures such as individualized goal setting, WeChat group interaction, peer support, family support, and continuous follow-up are adopted to strengthen the positive experience of patients' active behavior and promote the long-term maintenance of exercise behavior. The innovation of this study lies in the first time that a multiple theoretical model is systematically applied to the entire process of exercise behavior management during dialysis for elderly MHD patients, integrating the behavior change theory with exercise intervention during dialysis. Different from previous studies that only focus on exercise form or exercise intensity, this study pays more attention to "how to promote patients to persist in exercise for a long time," and constructs a continuous intervention path of "exercise training + behavior management + continuous support" through social support, behavior reinforcement, and continuous feedback mechanisms. The research results show that this model can form an "exercise improves function—function enhances confidence—confidence promotes persistence" positive cycle, thereby improving patients' exercise initiative and long-term compliance. Therefore, the exercise intervention model based on multiple theoretical models during dialysis not only helps to improve the patients' functional status, but also provides a new theoretical basis and practical reference for the long-term behavior management and continuous rehabilitation care of hemodialysis patients.

6. Summary

This study constructs an exercise intervention plan based on multiple theoretical models and applies it to elderly MHD patients. The results show that this intervention model can effectively improve the patients' physical function, lower limb muscle strength, and exercise endurance, while enhancing exercise self-efficacy and exercise compliance. With the extension of intervention time, the exercise behavior and functional status of the patients show a continuous improvement trend. The innovation of this study lies in integrating the multiple theoretical model system into the entire process of exercise behavior management during dialysis, not only focusing on exercise training itself, but also emphasizing the establishment and long-term maintenance of exercise behavior. Through strategies such as behavior initiation, behavior maintenance, social support, and continuous follow-up, a comprehensive intervention model combining "exercise training + behavior management + continuous support" is constructed, which helps to promote patients' long-term exercise persistence and form a continuous healthy behavior cycle. Therefore, the exercise intervention model based on MTM during dialysis is more in line with the characteristics of long-term chronic disease management for elderly MHD patients, and provides new intervention ideas for the long-term exercise behavior management and continuous rehabilitation care of elderly MHD patients.

However, it should be pointed out that the sample size of this study is small, which may limit the statistical test efficacy and the extrapolation ability of the research conclusion to some extent. At the same time, since the intervention only lasted for 12 weeks, the long-term benefits of this intervention are not yet very clear. Further research is recommended to further improve the exercise intervention plan based on multiple theoretical models and to adopt a multi-center, large-sample randomized controlled trial design, so as to better test the potential of the application of this plan.

Disclosure statement

The authors declare no conflict of interest.

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