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The effect of regular exercise combined with quantitative nutritional support on immune function indicators such as CD3+, CD4+, CD8+, and nutritional status in dialysis patients.

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Keywords: hemodialysis; immune function; nutritional status.

Abstract. To study the effect of regular exercise and quantitative nutritional support on dialysis patients' immune function indicators and nutritional status, 100 uremic patients who underwent hemodialysis treatment in our hospital from February 2021 to February 2023 were selected as the study subjects. They were divided into a control group (n=50) that received regular exercise and routine nutritional support, and a research group (n=50) that received regular exercise and quantitative nutritional support. This study compared the baseline levels of nutritional indicators such as prealbumin (PA), transferrin (TF), serum albumin (SAB), and hemoglobin (HB); cellular immune indicators such as CD3+, CD4+, and CD8+; as well as humoral immune indicators such as immunoglobulin A (IgA), immunoglobulin G (IgG), and immunoglobulin M (IgM) at enrollment and after three months of intervention. At the time of enrollment, there were no significant differences in nutritional indicators between the two groups of patients ($p>0.05$), nor in the levels of cellular immune indicators ($p>0.05$) or humoral immune indicators ($p>0.05$). After three months of intervention, nutritional indicators such as PA in all patients in the experiment grew ($p<0.05$), and those in the research group exceeded the control group ($p<0.05$). Similarly, the levels of CD3+ and other cellular immune indicators and the concentrations of IgA and other humoral immune indicators increased in both groups after three months of intervention ($p<0.05$). However, these increases were higher in the research group than in the control group ($p<0.05$). Regular exercise combined with quantitative nutritional support can effectively improve hemodialysis patients' nutritional index levels, nutritional status, immune index levels, and immune function.

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Efecto del ejercicio regular, combinado con soporte nutricional cuantitativo, sobre indicadores de la función inmune tales como CD3+, CD4+, CD8+, y el estado nutricional en pacientes en diálisis.

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Palabras clave: hemodiálisis; función inmune; estado nutricional.

Resumen. Para estudiar el efecto del ejercicio regular y el apoyo nutricional cuantitativo sobre los indicadores de función inmune y el estado nutricional de los pacientes en diálisis, se seleccionaron como sujetos de estudio 100 pacientes urémicos que se sometieron a tratamiento de hemodiálisis en nuestro hospital desde febrero de 2021 hasta febrero de 2023. Se dividieron en un grupo control (n=50) que recibió ejercicio regular y apoyo nutricional de rutina y un grupo de investigación (n=50) que recibió ejercicio regular y apoyo nutricional cuantitativo. Este estudio comparó los niveles basales de indicadores nutricionales como prealbúmina (PA), transferrina (TF), albúmina sérica (SAB) y hemoglobina (HB); indicadores inmunes celulares tales como CD3+, CD4+ y CD8+; así como indicadores inmunes humorales como inmunoglobulina A (IgA), inmunoglobulina G (IgG) e inmunoglobulina M (IgM) al momento de la inscripción y después de tres meses de intervención. En el momento del reclutamiento, no hubo diferencias significativas en los indicadores nutricionales entre los dos grupos de pacientes (p>0,05), ni en los niveles de indicadores inmunes celulares (p>0,05) o indicadores inmunes humorales (p>0,05). Después de tres meses de intervención, los indicadores nutricionales como la PA en todos los pacientes del experimento aumentaron (p<0,05), y los del grupo de investigación superaron al grupo control (p<0,05). De manera similar, los niveles de CD3+ y otros indicadores inmunes celulares y las concentraciones de IgA y otros indicadores inmunes humorales aumentaron en ambos grupos después de tres meses de intervención (p<0,05). Sin embargo, estos aumentos fueron mayores en el grupo de investigación que en el grupo control (p<0,05). El ejercicio regular combinado con apoyo nutricional cuantitativo puede mejorar eficazmente los niveles de índices nutricionales, el estado nutricional, los niveles de índices inmunológicos y la función inmune de los pacientes en hemodiálisis.

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INTRODUCTION

Hemodialysis (HD) is a renal replacement therapy commonly used in patients with advanced or end-stage renal disease. Diabetes nephropathy accounts for a high proportion of HD, which is consistent with the increasing trend of the number of diabetes patients [1]. When the kidneys lose normal function, HD draws the patient's blood out of the body, simulates kidney function through a special filter to remove waste, toxins, and excess water from the body, and then reinfuses the purified blood back into the patient's body to maintain water-electrolyte and acid-base balance. This process can help patients maintain and improve their quality of life [2]. However, at the same time as treatment, patients may experience complications such as malnutrition [3].

During the HD process, waste and excess water in the patient's body are discharged through a dialyzer, which may increase the patient's metabolic rate and energy consumption. Dialysis patients must limit their intake of substances such as sodium, potassium, and phosphorus during and between treatment periods while also controlling their water intake, which may lead to loss of appetite and reduced intake. When energy intake is insufficient to meet the patient's metabolic needs, it can lead to energy expenditure exceeding the intake, leading to malnutrition [4]. During dialysis, some nutrients and proteins may be removed along with the waste, leading to protein loss. The inflammatory response and chronic inflammatory state during dialysis may lead to metabolic disorders, promote protein breakdown, accelerate protein loss, and lead to malnutrition [5]. The causes of HD malnutrition include both iatrogenic and non-iatrogenic factors. Possible factors related to iatrogenic factors include poor dialysis adequacy and excessive loss of serum albumin during dialysis, while non-iatrogenic factors include poor appetite and insufficient nutrition supplementation. These factors can be changed and incorporated into the nutritional assessment [6].

When dialysis patients are in a state of severe metabolic stress, a sharp decrease in serum albumin and a significant decrease in albumin and hemoglobin are usually observed. These changes are usually accompanied by a deterioration in the overall health status of patients and are unlikely to respond to adjustments in dialysis plans. In such cases, targeted nutritional interventions and protein supplementation must be used during dialysis [7]. Protein-energy malnutrition and deficiency of single nutrients can affect immune responses [8]. When immune cells are activated, they can meet nutritional needs through anaerobic respiration. Signals from adipose tissue limit the activity and quantity of immune cells in nutrient-deficient situations [9]. Under malnutrition, the secretion of adipokines is dysregulated, affecting the activity of immune cells and leading to an increased susceptibility of inflammatory autoimmune reactions to infectious diseases[10]. Long-term protein deprivation correlates the degree of malnutrition in body weight with the antibody response in the humoral immune response [11]. Nutritional metabolism is related to the differentiation and function of various immune cells, and nutritional intervention can manipulate immune cell function. Nutritional intervention can enhance nutritional status, affecting immune cell dynamics [12]. This study applies regular exercise combined with quantitative nutritional intervention to HD patients and analyzes its effectiveness.

PATIENTS AND METHODS

General Information: The research subjects of this study consisted of 100 uremic patients who received HD treatment in our hospital from February 2021 to February 2023. The patients knew the purpose of the research, agreed to participate, and signed an informed consent form. <u>Inclusion criteria</u>: (a) Dialysis time≥6 months. (b) Age≥18 years old. (c) Regular dialysis 2-3 times a week. (d) Comply with the diagnostic criteria for malnutrition in the GLIM Malnutrition Diagnostic Standards - Global Consensus Report in Clinical Nutrition receive nutritional support. (e) Stable conditions, electrolyte disorders, acidosis, and other uremic signs have been effectively controlled. <u>Exclusion criteria:</u> (a) Concomitant acute gastrointestinal diseases. (b) Concomitant malignant tumors and other malignant consumptive diseases. (c) Presented diseases that affect metabolism, such as hyperthyroidism and adrenal diseases. (d) Significant edema of pleural and abdominal effusion. (e) The combination of severe depression and recent poor appetite that led to a decrease in body mass index. Other exclusion criteria: (a) deterioration of the condition or death during the study. (b) Missing visits. (c) Automatic exit. This study included 100 patients, with no excluded cases. Upon meeting the inclusion criteria, participants were randomly assigned into two groups to ensure comparability and to minimize selection bias. Data were systematically collected at two distinct time points: baseline data at the beginning of the study and follow-up data upon intervention completion. Eighty valid data were collected, and the effective data recovery rate was 100%. There were no significant differences in general information such as gender, age, body mass index, and primary disease between the two groups of patients (p>0.05), as shown in Table 1.

Method: A nutritional assessment was conducted on the included patients, and their nutritional status was evaluated based on the Malnutrition Universal Screening Tool (MUST). BMI ≥ 20.0 was scored as 0. A BMI between 18.5 and 20.0 was 1 point. BMI ≤ 18.5 was 2 points, or weight loss within 5% in the past 3-6 months was 0 points. Weight loss between 5% and 10% in the past 3-6 months was 1 point. Weight loss of more than 10% in the past 3-6 months was 2 points. Fasting or consuming food less than five days due to acute illness was 2 points. A score of 0 indicates a low nutritional risk state, and regular nutritional screening is sufficient. A score of 1 indicated a moderate nutritional risk state, requiring recording dietary intake status within three days and repeated screening. A score of 2 or more indicated a high-risk state and required nutritional intervention. After evaluation, the patient's BMI was ≤ 18.5, indicating a high-risk state and requiring nutritional intervention.

Control Group (CG): Regular exercise combined with routine nutritional support. Regular exercise: When patients came to the hospital for treatment, exercise education was carried out, and patients were advised to take moderate walks indoors and outdoors and engage in mild aerobic exercises such as jogging, cycling, and swimming. Exercise should be carried out 2 hours after meals, and loose and breathable clothes suitable for the ambient temperature should be worn. Before and after exercise, measuring the pulse and keeping records was necessary. If there was any discomfort during exercise, it should have to be stopped immediately, and excessive exercise should be avoided. The frequency of exercise was 3-5 times a week, and the heart rate of exercise needed to be 20 times/min higher than the resting rate. Each walk took 2-3 minutes and required 2-3 minutes of rest, with an average of 60-80 steps per minute, alternating. Nutritional support: Based on the patient's condition and dietary habits, it was essential to know

Table 1
Comparison of general information between two groups of patients.

Group	n	Gender		Age (years)	BMI (kg/m^2)	Primary disease			
		Male	Female			Chronic glomerulonephritis	Diabetic nephropathy	Polycystic kidney	Other
Control Group	50	28 (56)	22 (44)	56.56±12.36	18.49±3.21	13 (26)	15 (30)	11 (22)	11 (22)
Research Group	50	30 (60)	20 (40)	57.12±12.40	18.50±3.20	14 (28)	14 (28)	10 (20)	12 (24)
χ^2/t	-	0.164		0.226	0.016	0.163			
p	-	0.685		0.822	0.988	0.983			

Values are expressed as n (%) or X±SD.

how to correctly use scale tools such as salt spoons and oil cups to help patients match their daily meals and master nutritional support. Then, it was necessary to encourage patients to record and grasp their nutritional intake. Weekly dietary surveys needed to be conducted on patients, and timely guidance and supplementation should be provided for any unreasonable situation. It is also necessary to correct unhealthy dietary habits and adjust dietary plans.

Research group (RG): In the study, the rRG received a comprehensive nutritional intervention that included both a specialized nutrient formula and a tailored food plan. The nutritional support was twofold: (a) Specialized Nutrient Formula: The RG was provided with a specially formulated oral nutrient solution designed to meet the specific needs of hemodialysis (HD) patients. The formula composition was based on individual protein and energy requirements. Daily protein needs were calculated at 0.8 to 1.2 grams per kilogram of body weight. Energy requirements for males and females were determined using separate formulas: for males, the formula used was 88.362 + (13.397 × weight in kg) + (4.799 × height in cm) - (5.677 × age in years); for females, the formula was 447.593 + (9.247 × weight in kg) + (3.098 × height in cm) - (4.330 × age in years). The nutrient solution was composed of a blend containing 1-9% protein, 1-20% maltodextrin, 1-10% plant mixed oils, 0.1-1% borage oil, 1-15% corn syrup solids, 1-5% sugar, 1-2% cellulose, 0.1-1% essential minerals, 0.01-0.1% emulsifier, and 0.01-0.05% L-carnitine and L-taurine. The RG members were instructed to consume this nutrient solution 200-250 mL per session, 6-7 times daily, ensuring each feeding was completed within 15-20 minutes and spaced at least two hours apart. (b) Tailored Food Plan: In addition to the nutrient solution, patients in the RG were provided with a food plan tailored to their needs and dietary habits. This plan was not solely based on the consumption of the nutrient solution but was supplemented by regular meals. The food plan aimed to ensure that patients received a balanced diet, taking into account their daily total energy and nutrient requirements. Fat intake was targeted to provide 30% of the total daily calorie intake, and carbohydrates were to account for 50%. Patients were educated on using tools like salt spoons and oil cups to properly portion their meals and were encouraged to maintain a record of their nutritional intake. Weekly dietary surveys were conducted to offer personalized guidance and to make any necessary adjustments to their diet. (c) The combination of the nutrient solution and the tailored food plan was designed to ensure that patients in the RG received adequate nutrition to address their high-risk nutritional state, as identified by the Malnutrition Universal Screening Tool (MUST). Additionally, patients were advised to consume fruit and vegetable juices between feedings, with a hydration goal of 500 mL of water plus the volume of the previous day's urine output. Weekly follow-ups via WeChat phone calls by nurses helped monitor the patient's adherence to the feeding regimen and provided an opportunity for ongoing nursing guidance, including reminders about the importance of nutrient tube maintenance and timely follow-up appointments.

Electronic records of follow-up data.

Outcome Measures

Nutritional status: At the time of enrollment, fasting peripheral venous blood was collected from patients from 6:00 to 7:00 in the morning during the intervention period of three months. After centrifugation, serum was collected for nutritional indicators, including PA, TF, SAB, and HB. PA standard reference range= 0.20-0.40 g/L. TF's typical reference range = 2.5-4.3 g/L. SAB typical reference range = 35-55 g/L. HB normal reference range=110~160 g/L.

Immunity

Cellular immune indicators: At the time of enrollment, the patient's fasting peripheral venous blood was collected from 6:00 to 7:00 in the morning for cellular immune index testing during the intervention period of three months. The detection indicators include CD3+, CD4+, and CD8+. The normal reference range for CD3+ was 955-2860/μL. CD4+normal reference range= 450~1440/μL. CD8+ normal reference range= 320~1250/μL.

Humoral immune indicators: At enrollment, fasting venous blood was collected from patients at 6:00 to 7:00 in the morning for humoral immune index testing during the intervention period of three months. The detection indicators include IgA, IgG, and IgM, and the normal reference range of IgA is 0.71-3.85 g/L. Normal reference range of lgG =7.0-16.6 g/L. IgM typical reference range = 0.4-3.45 g/L.

Statistical analysis: IBM SPSS 26.0® was used for data processing, and the measurement data was expressed as mean ± standard deviation ($\bar{x}$±SD). According to the Kolmogorov-Smirnov test, the measurement data conformed to a normal distribution, with independent t-tests performed between groups and paired t-tests performed within groups. Graph Pad Prism 8 was used to draw a bar-separated scatter plot of indicator horizontal changes. The number of cases used in technical data, expressed as a percentage (n,%), was subjected to the χ^2 test, and $p<0.05$ was considered statistically significant.

RESULTS

Comparison of nutritional status between the two groups of patients

At the time of enrollment, there was no significant difference in the levels of PA, TF, SAB, and HB nutritional indicators between the two groups of patients ($p>0.05$). After intervention for three months, the levels of nutritional indicators such as PA in all patients in the experiment grew ($p<0.05$), while the RG group exceeded the CG group ($p<0.05$), as shown in Table 2.

Comparison of cellular immune indicators between the two groups of patients

At the time of enrollment, there were no significant differences in the levels of cellular immune indicators such as CD3+, CD4+, and CD8+ between the two groups of patients ($p>0.05$). At the time of intervention for three months, the levels of CD3+ and other cellular immune indicators in both groups of patients increased ($p<0.05$), while the RG exceeded the CG ($p<0.05$), as shown in Table 3.

Table 2
Comparison of nutritional index levels between the two groups of patients.

Group	n	PA (g/L)		TF (g/L)		SAB (g/L)		HB (g/L)	
		Baseline Parameters	At three months of intervention	Baseline Parameters	At three months of intervention	Baseline Parameters	At three months of intervention	Baseline Parameters	At three months of intervention
Control group	50	0.17±0.07	0.30±0.86*	2.30±0.31	2.96±0.26*	33.90±1.07	35.79±3.85*	106.74±8.11	114.85±5.73*
Research group	50	0.16±0.07	0.34±0.57*	2.30±0.33	3.15±0.40*	33.74±1.06	37.11±2.17*	104.82±6.27	117.44±5.16*
t	-	0.256	2.463	0.041	2.170	0.777	2.110	1.325	2.375
p	-	0.799	0.016	0.968	0.032	0.439	0.037	0.188	0.020

PA: pre albumin. TF: transferrin. SAB: serum albumin. HB: hemoglobin.
Values are expressed as X±SD; *p<0.05 compared to levels at admission to the study.

Table 3
Comparison of cellular immune index levels between the two groups of patients.

Group	n	CD3+(μL)		CD4+(μL)		CD8+(μL)	
		Baseline Parameters	At three months of intervention	Baseline Parameters	At three months of intervention	Baseline Parameters	At three months of intervention
Control Group	50	944.74±21.05	974.04±24.64*	441.30±16.31	465.67±27.42*	313.38±14.93	364.68±20.60*
Research Group	50	943.17±25.87	989.20±35.40*	442.11±18.57	479.95±27.49*	310.87±15.41	373.82±16.74*
t	-	0.333	2.487	0.233	2.597	0.827	2.435
p	-	0.740	0.015	0.816	0.011	0.410	0.017

Values are expressed as X±SD *p<0.05 Compared to the time of admission.

Table 4
Comparison of humoral immune index levels between the two groups of patients.

Group	n	IgA (g/L)		IgG (g/L)		IgM (g/L)	
		Baseline Parameters	At three months of intervention	Baseline Parameters	At three months of intervention	Baseline Parameters	At three months of intervention
Control Group	50	0.70±0.06	1.26±0.09*	6.59±1.33	7.34±1.10*	0.39±0.05	1.57±0.08*
Research Group	50	0.68±0.06	1.31±0.10*	6.44±1.21	7.94±1.22*	0.38±0.04	1.62±0.10*
t	-	1.467	2.567	0.620	2.561	0.926	2.640
p	-	0.146	0.012	0.537	0.012	0.357	0.010

IgA: Immunoglobulin A. LgG: Immunoglobulin G. IgM: Immunoglobulin M. Values are expressed as X±SD. *p<0.05 compared to Baseline Parameters.

Comparison of humoral immune indicators between the two groups of patients

At the time of enrollment, a significant difference did not exist in the concentration of IgA, IgG, and IgM humoral immune indicators between the two groups of patients ($p>0.05$). At the time of intervention for three months, the levels of IgA and other humoral immune indicators in both groups of patients increased ($p<0.05$), and the RG exceeded the CG ($p<0.05$), as shown in Table 4.

DISCUSSION

Prealbumin PA, also known as thyroid binding protein, transports thyroid hormones [13]. Its main synthetic organ is the liver. In cases of malnutrition in the body, the synthesis of PA is affected, and its blood level decreases [14]. PA is often used as an essential indicator to evaluate the nutritional status of patients. During dialysis, HD patients excrete a certain amount of protein through dialysis, resulting in protein loss. The side effects of medication, the disease itself, and other factors in patients can lead to loss of appetite and affect dietary intake. Patients can also suffer malnutrition by limiting phosphorus, sodium, and potassium intake to control the fluid balance and avoid material accumulation in the blood [15]. TF is a protein responsible for iron transport, present in plasma and involved in HB synthesis and oxygen transport [16]. It absorbs iron from the intestines, spleen, and other tissues and transports it to the RBC in the bone marrow, synthesizing hemoglobin [17]. Iron metabolism can be evaluated by monitoring the level of TF in the blood. In cases of malnutrition, TF can undergo a decrease [18]. SAB is a rich protein in the blood synthesized by the liver and reaches the entire body through blood circulation, maintaining a balance between plasma and cells and avoiding the loss and retention of water and nutrients [19]. It participates in the binding and transportation of various substances, binds with free fatty acids, transports fatty acids to cells, participates in immune regulation of the body, and maintains acid-base balance [20]. Changes in SAB levels can reflect the nutritional status of patients. In HD patients with malnutrition, excessive protein loss affects liver protein synthesis, decreasing SAB levels [21]. HB is a Pro present in RBC and an essential component in the blood. It transports oxygen from the lungs to various tissues for oxygen exchange [22], and HB levels are commonly used to assess the degree of anemia in patients. Malnutrition may cause anemia and decreased HB [23]. For HD patients, long-term dialysis treatment may lead to chronic inflammatory reactions and iron loss, affecting RBC generation and HB levels [24].

Table 2 shows that regular exercise and quantitative nutritional support can improve patients' nutritional indicators. Quantitative nutritional intervention can develop personalized nutritional interventions based on the specific nutritional needs of patients, ensuring that patients consume sufficient Pro and other nutrients. Pro is the primary raw material for the synthesis of PA, and sufficient intake of Pro can promote the synthesis of PA. Regular exercise can promote Pro synthesis and increase muscle mass, which is the main storage area for Pro. Increasing muscle mass can increase Pro storage in the body. The pro breakdown can lead to a decrease in PA and transferrin levels. Regular exercise can reduce Pro breakdown, and quantitative nutritional interventions can increase Pro intake, thereby maintaining high Pro levels in patients.

The effect of regular exercise and quantitative nutritional intervention on cellular immune indicators in HD malnutrition patients. CD3+ is a cell surface marker that refers to lymphocytes carrying CD3 antigens. It mainly exists in the expression of T lymphocytes and is a part of T cell receptor complexes. In immunology, cell surface markers are identified and classified to distinguish different types of immune cells, and the number of T cells identified by CD3 labelling can be monitored [25]. CD4+ cells, also known as helper T cells, are critical immune cells in the immune system and influence the regulation and coordination of immune responses in the body [26]. CD4+ are mainly present in the peripheral blood and other parts of lymphatic tissue and participate mainly in the immune response of intracellular and extracellular pathogens, as well as the immune regulation of T cells. It suppresses the immune response through inhibitory cytokines, avoiding excessive immune response and autoimmune reactions [27]. CD8+ are cytotoxic T cells and essential immune cells in the immune system. They kill infected or mutated cells in the body [28]. When the body is invaded by pathogens such as bacteria and viruses, CD8+ cells can recognize and kill infected cells to prevent pathogen transmission [29]. The activity and function of CD8+ play a vital role in the immune system, protecting the body from pathogen infection and tumor invasion [30]. The important subpopulations of lymphocytes play an essential role in the immune response, and malnutrition may impact the immune system, leading to impaired immune function and affecting the level of lymphocyte subpopulations. Thus, malnutrition can lead to a decrease in the number of T cells or impaired function, leading to a decrease in the levels of CD3+, CD4+, and CD8+, affecting the normal regulatory function of the immune system [31]. Table 3 shows that regular exercise combined with quantitative nutritional support can effectively improve patients' cellular and humoral immune indicator levels. Analyzing the reasons, regular exercise combined with quantitative nutritional intervention can improve immune function and enhance the number and activity of T cells, and regular exercise can enhance the body's immune activity. Quantitative nutritional intervention can provide T cells with the required Pro and micronutrients, thereby increasing cellular immune indicators such as CD3+ levels, helping to enhance T cell function and immune response ability [32].

The effect of regular exercise and quantitative nutritional intervention on humoral immune indicators in HD malnutrition patients. IgA is an immunoglobulin mainly present on the surface of mucous membranes and body fluids, mainly on the surface of mucous membranes such as the respiratory and digestive tracts. It is a barrier to protect the mucosa from pathogen invasion and the first immune barrier. Abnormal levels of IgA may be related to certain immune diseases [33]. IgG is an immunoglobulin in bodily fluids and blood, synthesized by B lymphocytes and secreted during immune activation during infection, mainly involved in humoral immune responses. It can bind to pathogens, neutralize toxins, and activate the immune system, promoting pathogen clearance and destruction [34]. IgM is a crucial component of the humoral immune system and is the immunoglobulin first produced during early infection or initial exposure to antigens. It participates in humoral immunity and can quickly initiate immune responses, especially in early infections. It has a solid ability to agglutinate and activate complement, quickly neutralizing and clearing pathogens, thereby preventing the further spread of infection [35]. Pro is the main component of immunoglobulin [36]. Due to an insufficient supply of Pro, malnutrition patients limit immunoglobulin synthesis, decreasing the levels of related immunoglobulin indicators. Immunoglobulin plays a crucial role in maintaining the body's immune function, and malnutrition, leading to a decrease in immunoglobulin synthesis, may increase the risk of infection in patients. Therefore, providing reasonable nutritional support for HD malnutrition patients is crucial for improving their immune indicators and preventing infection [37,38]. Regular exercise, combined with quantitative nutritional intervention, could markedly enhance the immune index levels of patients, as shown in Table 4. Regular exercise can stimulate immune cell activity and enhance the body's ability to clear pathogens. Quantitative nutritional support ensures patients receive sufficient Pro supply through reasonable dietary adjustments and nutritional supplementation, an important immunoglobulin component. Recombinant Pro intake helps to increase the synthesis of immunoglobulin.

In conclusion, this study observed a significant effect of combining regular exercise with quantitative nutritional support in improving the nutritional indicators of HD malnutrition patients and also tested the levels of humoral and cellular immune indicators. The results show that regular exercise combined with quantitative nutritional support can also help improve immune function and have an auxiliary therapeutic effect on the immune function of HD malnourished patients. Its effect becomes more pronounced with the extension of intervention time. However, the sample size of this study is relatively small, and the specific efficacy needs to be confirmed by expanding the sample size. Secondly, the causes of malnutrition in dialysis patients involve multiple factors and mechanisms. This study only observed changes in nutritional indicators and levels of humoral cellular immune indicators, and its specific mechanisms require further research in animal experiments.

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Conflict of interest

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Contribution of authors

Both authors contributed equally to this study, and their efforts were equally significant in its completion.

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