STUDY PROTOCOL

A Randomized Controlled Trial of Different Exercise Modalities in Patients With Chronic Kidney Disease: A Longitudinal Study of Renal Outcomes and Potential Mechanisms

ClinicalTrials.gov Identifier

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Title {1a}

Longitudinal Study of Different Exercise Modalities in Chronic Kidney Disease: Effects and Preliminary Exploration of Underlying Mechanisms

Protocol Contributors {3a}

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Abstract

- **Background:** Chronic kidney disease (CKD) is a progressive condition characterized by a gradual decline in kidney function over time. It is generally diagnosed based on persistent reductions in glomerular filtration rate or evidence of kidney damage. Exercise interventions have beneficial effects on oxidative stress, inflammatory responses, hemodynamics, and metabolic function and have increasingly been used in the management and prognosis of kidney disease. However, studies systematically investigating the effects of different exercise modalities on kidney disease and their underlying mechanisms remain limited.
- **Objective:** This study aims to systematically investigate the effects of different exercise modalities on patients with CKD through a multistage follow-up intervention study, clarify their safety, effectiveness, and medium- to long-term value, and develop scientifically sound and feasible exercise intervention strategies. It will also preliminarily explore how different exercise modalities may affect CKD through mechanisms involving hemodynamic regulation, oxidative stress, and inflammatory responses, thereby providing experimental evidence for the biological mechanisms underlying exercise in CKD prevention and management.
- **Methods:** This randomized controlled trial will enroll patients with CKD and randomly assign them to an aerobic exercise group, a resistance exercise group, a combined exercise group, or a control group. The three exercise groups will undergo a 1-year exercise intervention consisting of three sessions per week, each lasting approximately 60 minutes. The control group will receive routine health education. Relevant outcomes will be assessed at baseline and at months 2, 4, 6, and 12. Primary outcomes include estimated glomerular filtration rate, serum creatinine, the four components of the blood lipid profile, blood glucose, urine protein, the urine albumin-to-creatinine ratio, and endogenous creatinine clearance.

Secondary outcomes include body fat percentage, grip strength, vital capacity, the 30-second chair stand test, 6-minute walk distance, and health survey measures of quality of life, sleep, and mental health. Hemodynamic parameters, including renal blood flow, renal arterial peak systolic velocity, end-diastolic velocity, and resistive index, will also be assessed. Inflammatory markers include C-reactive protein, tumor necrosis factor-alpha, interleukin-6, and interleukin-10. Oxidative stress markers include malondialdehyde, superoxide dismutase, and glutathione peroxidase. Renal fibrosis-related biomarkers include transforming growth factor-beta 1 and connective tissue growth factor. These assessments will be used to preliminarily investigate the potential mechanisms through which different exercise modalities may improve CKD.

● **Discussion:** This study is expected to clarify the effects of different exercise interventions on kidney function and overall health in patients with CKD, compare the effects of different exercise modalities, and investigate their potential mechanisms through the regulation of renal hemodynamics, oxidative stress, and inflammatory responses. The findings will provide data to support exercise management for patients with CKD and contribute to the development of comprehensive CKD prevention and management strategies.

● Trial registration: ClinicalTrials.gov; registration number pending. Registered on October 18, 2026. Retrospectively registered.

Keywords: Chronic kidney disease; aerobic exercise; resistance exercise; combined exercise; hemodynamics; inflammation; renal fibrosis and tubular injury; oxidative stress; randomized controlled trial.

Structured Summary {1b}

Item	Description
Primary trial registry and registration number {4}	Proposed registry: ClinicalTrials.gov. Registration number: pending. Registration date: October 18, 2026. Website: https://clinicaltrials.gov/
Other trial identifiers	Not applicable.
Sources of funding and material support	Basic Research Operating Expenses of the China Institute of Sport Science, General Administration of Sport of China (Basic 25-02 and 26-15).
Lead sponsor and contact details {3b}	China Institute of Sport Science, General Administration of Sport of China. Contact: Yuzhe Luo. Email: lyz2025n1@163.com.
Roles and responsibilities of the sponsor and funder {3c}	The funder will not participate in study design, data collection, statistical analysis, interpretation of results, or

	manuscript preparation.
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Public title	Longitudinal Study of the Effects and Mechanisms of Different Exercise Modalities in Chronic Kidney Disease.
Scientific title	Longitudinal Study of Different Exercise Modalities in Chronic Kidney Disease: Effects and Preliminary Exploration of Underlying Mechanisms.
Country/region of recruitment	China.
Health condition or problem studied	This study focuses on health management in patients with CKD and the effects of different exercise modalities on functional status, kidney function, and related biological markers.
Interventions	Participants will be randomly assigned to an aerobic exercise group, a resistance exercise group, a combined exercise group, or a control group. The three exercise groups will undergo a 1-year exercise intervention, while the control group will receive routine health education.
Key inclusion and exclusion criteria	**Key inclusion criteria:** Adults aged 30–60 years, of either sex, meeting the CKD diagnostic criteria in the Kidney Disease: Improving Global Outcomes (KDIGO) guidance and the *2023 Expert Recommendations on the Clinical Pathway for Early Screening of Chronic Kidney Disease and Its Complications in Chinese Adults*. Participants will include those with CKD stages G1–G2 (estimated glomerular filtration rate of 60–90 mL/min/1.73 m²) and stages G3–G4 (estimated glomerular filtration rate of 15–59 mL/min/1.73 m²) who have been assessed by a clinician as able to participate in exercise, have sufficient cognitive ability to complete the intervention, and voluntarily agree to participate and provide informed consent. **Key exclusion criteria:** Acute kidney failure; severe hypertension (above 180/110 mmHg); diabetes; heart failure; acute infection; malignancy or active immune disease; severe edema or musculoskeletal disease preventing exercise; or body mass index ≥35 kg/m².
Study type	Single-center, randomized, parallel-group controlled trial.
Planned date of first participant enrollment	June 26, 2026.
Sample size	A total of 120 participants are planned, with 30 participants in each group.
Primary outcomes	Estimated glomerular filtration rate, serum creatinine, the four components of the blood lipid profile, blood glucose, urine protein, the urine albumin-to-creatinine ratio, and endogenous creatinine clearance.

Secondary outcomes	Body fat percentage, grip strength, vital capacity, the 30-second chair stand test, 6-minute walk distance, and health survey assessments of quality of life, sleep, and mental health. Hemodynamic parameters include renal blood flow, renal arterial peak systolic velocity, end-diastolic velocity, and resistive index. Inflammatory markers include C-reactive protein, tumor necrosis factor-alpha, interleukin-6, and interleukin-10. Oxidative stress markers include malondialdehyde, superoxide dismutase, and glutathione peroxidase. Renal fibrosis-related biomarkers include transforming growth factor-beta 1 and connective tissue growth factor.
Ethics review	Science and Technology Ethics Review Committee of the China Institute of Sport Science, General Administration of Sport of China. Approval number: CISS20250814.
Individual participant data-sharing statement	The original study data will not be publicly shared. The data will be used by the research team only for study-related analyses, quality control, verification of results, and publication, within the scope of ethics approval and informed consent. Publications will report only aggregated statistical results and will not include personally identifiable information.
Protocol version {2}	Version 2.0, dated October 18, 2026.

Introduction

Background and Rationale {9a}

Chronic kidney disease is a progressive condition. Epidemiological surveys have estimated the global prevalence of CKD at approximately 14.3%. According to the Sixth China Chronic Disease and Risk Factor Surveillance, approximately 82 million adults in China had CKD in 2018–2019, corresponding to a prevalence of 8.2%. The Global Burden of Disease study reported that CKD rose from the 29th to the 18th leading cause of disability-adjusted life years between 1990 and 2019. CKD affects approximately 850 million people worldwide, accounting for 10% of the global population, and causes more than 1.2 million deaths annually. Some studies have projected that CKD will become the fifth leading cause of death worldwide by 2040, with one of the largest increases among diseases. The Global Kidney Health Atlas (2023) indicates that CKD affects people across different ages, ethnicities, and socioeconomic backgrounds. It increases the risk of complications such as cardiovascular disease, anemia, and disorders of bone metabolism, while substantially reducing quality of life and increasing the financial burden on families.

As a widely applicable non-pharmacological intervention, exercise has demonstrated important effects on oxidative stress, inflammatory responses, vascular function, and metabolic homeostasis. In recent years, exercise has increasingly been incorporated into the supportive treatment and prognosis management of CKD. Previous studies have shown that aerobic exercise can improve cardiorespiratory endurance, promote metabolic regulation, and potentially have beneficial effects on the decline in kidney function. Moderate-intensity aerobic exercise appears to provide greater benefits for patients with CKD than low-intensity aerobic exercise. Common forms include brisk walking, running, and swimming. These activities may improve renal blood flow and systemic circulation while also substantially improving cardiorespiratory endurance.

In recent years, resistance exercise has also been shown to have important benefits for CKD management and rehabilitation. Studies suggest that resistance exercise may reduce the risk of sarcopenia and improve functional capacity. Resistance exercise can also regulate inflammatory responses in patients with CKD. Moderate-intensity resistance exercise may reduce markers associated with malnutrition-inflammation syndrome, such as tumor necrosis factor-alpha, thereby potentially alleviating renal inflammation. One study reported that, among patients with severe CKD, resistance exercise performed twice weekly at 70% intensity for six months significantly reduced serum C-reactive protein levels and delayed the progression of renal fibrosis. However, evidence regarding the relative benefits of different exercise modalities in patients with CKD remains limited, particularly with respect to comparisons among aerobic exercise, resistance exercise, and combined exercise.

Furthermore, the potential mechanisms through which exercise improves clinical outcomes in patients with CKD remain incompletely understood. Patients with CKD often experience reduced renal blood flow, which is closely associated with microvascular structural damage and decompensated states of glomerular hyperperfusion and hyperfiltration. Persistent hemodynamic stress may lead to glomerulosclerosis and tubulointerstitial fibrosis. The development and progression of CKD involve multiple interacting mechanisms, including mitochondrial homeostasis imbalance, oxidative stress, hemodynamic abnormalities, and excessive activation of the renin–angiotensin system. Existing evidence suggests that exercise may exert renoprotective effects by regulating oxidative stress, inflammatory responses, metabolic disturbances, and renal fibrosis. However, evidence for these mechanisms in human populations remains limited. Therefore, systematic randomized

controlled studies are needed to evaluate different exercise modalities across functional performance, kidney function parameters, and related biomarkers. Accordingly, this study will compare the effects of aerobic exercise, resistance exercise, and combined exercise on physical function, kidney function, and related biological markers in patients with CKD. It will further explore potential mechanisms involving hemodynamics, oxidative stress, inflammatory responses, and renal fibrosis, providing a basis for more precise and individualized exercise interventions for CKD.

Rationale for the Choice of Control Intervention {9b}

Routine health education will be used as the control intervention to evaluate the additional effects of different exercise modalities compared with routine health education. This control approach cannot fully control for differences in participants' baseline physical activity, subsequent participation in other exercise, or dietary habits. These potential influences will be discussed as limitations when interpreting the results. Health education for the control group will cover healthy eating and lifestyle practices, chronic disease management, and recommendations for daily physical activity. Health education is recommended at least once per week. The control group will not receive structured exercise training. General exercise guidance materials may be provided to the control group after the study is completed.

Objectives {10}

This study aims to evaluate the effects of one year of aerobic exercise, resistance exercise, and combined exercise on exercise function, kidney function, and metabolic parameters in patients with CKD, and to compare the effects of these exercise modalities. By assessing hemodynamic, inflammatory, oxidative stress, and renal fibrosis-related biomarkers, the study will preliminarily explore the potential mechanisms through which exercise may improve CKD. Adverse events will also be monitored throughout the exercise intervention to evaluate the safety and feasibility of different exercise modalities in patients with CKD.
Methods: Patient and Public Involvement and Trial Design

Patient and Public Involvement {11}

Patients and members of the public were not involved in the study design, protocol development, or reporting of results. Before the formal start of the study, the research team will use questionnaires to collect information from prospective participants, including basic

demographic information, information relevant to the inclusion and exclusion criteria, days and times available for supervised group exercise each week, usual exercise frequency, and exercise preferences. This information will be used to understand participants' circumstances and exercise participation needs and to arrange supervised exercise sessions and intervention management procedures appropriately.

Before testing, researchers will explain the study objectives, exercise intervention procedures, training arrangements, assessment items, potential benefits, and possible risks in detail and will invite participants to provide feedback on the study arrangements. Assessments and subsequent exercise interventions will begin after participants have understood and agreed to the study and have completed informed consent. After the study, the findings will be disseminated through academic publications, conferences, and other appropriate channels. Overall study results will also be shared with participants when appropriate.

Trial Design {12}

This study will use a randomized, parallel-group design to evaluate the effects of different exercise modalities on functional status, kidney function, and related biological markers in patients with CKD. Eligible participants will be randomly assigned to the aerobic exercise group, resistance exercise group, combined exercise group, or control group and will receive the corresponding intervention.

Assessments will be conducted at baseline (T0) and at months 2 (T1), 4 (T2), 6 (T3), and 12 (T4) of the intervention to examine changes in the effects of different exercise modalities over time. Different group-specific notifications and separate training time slots will be used to reduce contact and communication between participants in different groups and thereby minimize intervention contamination. Assessor blinding will be used: outcome assessments will be conducted by researchers who are not involved in delivering the exercise interventions, thereby reducing measurement bias. Exercise adherence, training completion, and adverse events will be recorded throughout the study to evaluate the effectiveness, safety, and feasibility of the different exercise modalities.

Methods: Participants, Interventions, and Outcomes

Trial Setting {13}

The study is planned to take place at the Health Management Center of Beijing Aerospace General Hospital, Beijing, China. Participants will be recruited through routine health

examinations, clinical services for patients with CKD, and on-site and online recruitment by the research team. Study facilities will include areas for physical fitness assessment, exercise interventions, and relevant examinations. Participants will complete baseline assessments, exercise interventions, and follow-up measurements under the guidance of research personnel. All exercise sessions will be delivered by trained researchers according to a standardized protocol. Hospital medical or nursing staff may assist in managing emergencies during the study.

Characteristics of the Intended Study Population

Characteristic	Intended population
Age	Adults aged 30–60 years with CKD.
Sex	Eligible men and women.
Gender	Gender as self-reported by participants will be recorded.
Race, ethnicity, and ancestry	Primarily Chinese adults aged 30–60 years with CKD; all participants are expected to be Han Chinese.
Socioeconomic status	May be described by educational attainment, occupation, and related characteristics.
Geographic location	Participants will be recruited at Beijing Aerospace General Hospital in Beijing, China.
Other trial-related characteristics	Patients with CKD stages G1–G4, without contraindications to exercise, who meet the eligibility criteria.

Eligibility Criteria for Participants {14a}

Inclusion criteria

1．Aged 30–60 years, of either sex.

2．Meets the CKD diagnostic criteria in the Kidney Disease: Improving Global Outcomes (KDIGO) guidance and the 2023 Expert Recommendations on the Clinical Pathway for Early Screening of Chronic Kidney Disease and Its Complications in Chinese Adults. Two categories of participants will be included: individuals with early-stage CKD, stages G1 and G2, with an estimated glomerular filtration rate of 60–90 mL/min/1.73 m²; and individuals with established CKD, stages G3 and G4, with an estimated glomerular filtration rate of 15–59 mL/min/1.73 m², who have been assessed by a clinician as able to participate in exercise.

3．Clinically stable, with no dialysis or kidney transplantation within the previous six months.
4．No severe cardiopulmonary dysfunction or other contraindications to exercise.
5．Sufficient cognitive ability to comply with the intervention plan.
6．Willing to participate in the study and provide written informed consent.

Exclusion criteria

1．Acute kidney failure; severe hypertension (above 180/110 mmHg); diabetes; heart failure; acute infection; malignancy; or active immune disease.
2．Participation in another clinical trial or structured exercise intervention program within the previous three months.
3．Severe edema, musculoskeletal disease, or other conditions that prevent participation in exercise.
4．Body mass index ≥35 kg/m².
5．Pregnancy or plans to become pregnant.
6．Severe cognitive impairment or inability to cooperate with the study.

Withdrawal or removal criteria

1．Discovery after enrollment that the participant does not meet the study inclusion criteria.
2．Inability to complete the study or loss to follow-up during the study.
3．Voluntary withdrawal at the participant's request.
4．Development during the study of a disease, injury, or medical event that makes continued exercise training or testing inappropriate.
5．Failure to complete primary outcome assessments when valid repeat assessments cannot be obtained.
6．Withdrawal recommended by the investigator on safety grounds.

Eligibility Criteria for Study Centers and Intervention Providers {14b}

The study will be conducted at Beijing Aerospace General Hospital, China. The site has access to medical resources throughout the day, safe space for group exercise, physical fitness testing areas, rest areas, questionnaire completion areas, and interview areas. Licensed physicians will be available to assist with health assessments and the management of emergencies.

Interventions will be delivered by exercise intervention personnel or research team members who have received standardized training. Before training begins, intervention providers must be familiar with the study intervention manual, safety stopping criteria, rating of perceived exertion (RPE) recording, exercise modification procedures, and adverse event reporting procedures.

Informed Consent {32a}

Researchers will provide prospective participants and their family members with study information describing the objectives, procedures, potential benefits and risks, right to withdraw, and principles of data confidentiality. Eligible individuals will sign written informed consent after they have received and understood the study information.

Additional Consent Provisions for the Collection and Use of Participant Data and Biological Specimens {32b}

Blood and urine samples will be collected after participants have been informed and have provided consent. The collected biological specimens will be used only for the assessment of kidney function, metabolic parameters, inflammatory markers, oxidative stress-related markers, and other outcome measures specified in this protocol. The specimens will not be used for purposes outside this study unless additional ethics approval has been obtained and informed consent has been obtained again.

Interventions and Control

Description of Interventions and Control Measures {15a}

The intervention groups will receive one year of exercise training and will be divided into an aerobic exercise group, a resistance exercise group, and a combined exercise group according to exercise modality. All exercise interventions will follow a prespecified standardized training protocol and will be guided by researchers who have received standardized training. Participants will complete at least one supervised, in-person group exercise session each week. The remaining sessions will be completed independently, with exercise data recorded using a fitness band and uploaded. Each session will last 60 minutes, with three sessions per week. Training will consist of warm-up, main exercise, and stretching and cool-down components. The specific exercise modality will depend on group assignment.

The aerobic exercise group will primarily undertake moderate- to high-intensity indoor aerobic exercises, such as high knees in place, jumping jacks, continuous knee-to-elbow movements, or other progressions and regressions appropriate to each participant's exercise capacity. Maximum heart rate will be estimated using the Tanaka formula, and 55%–80% of estimated maximum heart rate will be used as the target exercise intensity range, with individualized adjustments based on participants' circumstances. During exercise, a Huawei fitness band in “free training” mode will record session duration, exercise heart rate, and related training data to monitor exercise intensity and completion. Each session will last 60 minutes, three times per week.

The resistance exercise group will follow a progressive resistance training program using resistance bands and bodyweight exercises, selected for safety and broad applicability. Examples include resistance-band chest presses, resistance-band rows, squats, and other progressions or regressions appropriate to participants' exercise capacity. Resistance bands and loads will be selected according to baseline exercise capacity and training level, with an intensity at which participants experience a clear sense of muscular fatigue after 10–15 repetitions. Resistance intensity will be adjusted primarily according to participants' perceived exertion, using the rating of perceived exertion (RPE) to assess training load and progressively increase difficulty. Training records will focus on exercise completion, training load, number of repetitions, fatigue, and discomfort. Each session will last 60 minutes, three times per week.

The combined exercise group will undertake both aerobic and resistance exercise according to the planned training program, including aerobic training, resistance training, and necessary functional exercises. If participants cannot attend both aerobic and resistance group sessions in the same week, they may alternate between aerobic exercise in one week and resistance exercise in the next. The planned weekly schedule is one resistance exercise session and two aerobic exercise sessions, each lasting 60 minutes. The principles for controlling exercise intensity will be the same as those used in the aerobic and resistance exercise groups, respectively.

During all exercise sessions, researchers will record session duration, completion, exercise intensity, changes in heart rate, training modifications, and exercise-related adverse events. The research team will periodically review training records to assess adherence and consistency of intervention delivery. If participants experience marked fatigue, chest

tightness, dizziness, pain, shortness of breath, or other discomfort during exercise, the intensity will be adjusted or training will be paused, followed by a safety assessment. During the study, participants will maintain their existing medication regimens, dietary habits, and daily lifestyles. The research team will not actively alter their usual disease management plans.

The control group will receive routine health education without structured exercise training. Educational content will include information about CKD, healthy lifestyle guidance, recommendations for daily physical activity, and advice on disease management. General exercise materials and guidance may be provided to control group participants after the study.

Table 1. Intervention Components and Progression Principles

Component	Duration	Main content	Progression principles
Warm-up	3–5 minutes	Joint mobility and low-intensity dynamic activities	Gradually mobilize the joints and activate the muscles.
Aerobic training	40–50 minutes	High knees, half-squat step jacks, boxing steps, V-steps with arm movements, knee raises with torso rotation and elbow contact, and jumping jacks	Use 55%–80% of estimated maximum heart rate as the reference range and adjust individually.
Resistance training	40–50 minutes	Resistance-band exercises, bodyweight squats, single-leg deadlifts, and calf raises	Begin with low resistance and fewer sets, then gradually increase the number of sets or resistance.
Stretching and cool-down	3–5 minutes	Upper- and lower-body stretching, breathing regulation, and cool-down activities	Avoid pain and excessive stretching.

Criteria for Discontinuing or Modifying Assigned Interventions or Control Measures {15b}

During the exercise intervention, individualized adjustments will be made according to participants' exercise tolerance and training performance. For the aerobic exercise group and the aerobic component of the combined exercise group, heart rate during exercise will be recorded using a Huawei fitness band, and 55%–80% of estimated maximum heart rate

calculated using the Tanaka formula will serve as the target intensity range. If a participant's exercise heart rate remains below the target range for two consecutive sessions and the prescribed training can be completed without difficulty, exercise duration may be increased, movement speed may be raised, or exercises may be progressed or replaced. If heart rate remains above the target range during exercise, or if the participant experiences marked fatigue, chest tightness, dizziness, shortness of breath, or other discomfort, exercise intensity must be reduced or training suspended, followed by a safety assessment.

For the resistance exercise group and the resistance component of the combined exercise group, training intensity will be assessed using the RPE scale. If a participant reports an RPE score of ≤3 for two consecutive sessions and demonstrates good exercise technique, training may be progressed by increasing repetitions, adding sets, or gradually increasing resistance. If the RPE score reaches ≥8, or if marked muscle pain, joint discomfort, compensatory movement, dizziness, chest tightness, substantial pain, shortness of breath, abnormal facial color, unsteady gait, or other concerning symptoms occur, training difficulty must be reduced or exercise suspended immediately, followed by a safety assessment.

If a participant develops a disease, injury, or medical event that makes continued exercise training or testing inappropriate, the investigator may recommend temporarily suspending, reducing, modifying, or discontinuing the intervention on safety grounds.

Strategies to Improve Adherence to Interventions and Control Measures {15c}

The research team will promote adherence through fixed weekly supervised exercise times, exercise check-ins using the mini-program, heart-rate data and RPE feedback, individualized progression or regression of exercise difficulty, attendance records, training logs, and management of adverse events. An attendance rate below 70% will not be a criterion for withdrawal but will exclude the participant from the per-protocol analysis. The research team will nevertheless make every effort to complete T1–T4 outcome assessments and will include the participant in the intention-to-treat analysis.

Concomitant Treatments Allowed or Prohibited During the Trial {15d}

Participants will maintain their usual daily habits and routines during the study. The research team will not change their existing medications, diets, or chronic disease management plans. If participants experience pain, falls, abnormal blood pressure, cardiovascular symptoms, or

other medical problems during the study, medical staff at Beijing Aerospace General Hospital will prioritize their care. The training plan will be suspended or modified after assessment. If participants engage in additional structured exercise interventions during the study, the type and amount of exercise will be recorded as appropriate. If the additional exercise cannot be quantified, it may be recorded as a protocol deviation.

Ancillary Care and Post-Trial Medical Arrangements {34}

After the study, the research team will provide both intervention and control groups with the exercise programs, appropriate exercise recommendations, and health education materials. After completing the T4 assessment, the control group may receive exercise guidance consistent with the core principles used in the intervention groups, together with all relevant materials.

Outcomes {16}

The primary outcomes of this study include kidney function and metabolic parameters. Kidney function will be assessed using estimated glomerular filtration rate, serum creatinine, urine protein, the urine albumin-to-creatinine ratio, and endogenous creatinine clearance. Estimated glomerular filtration rate will reflect glomerular filtration function; serum creatinine and endogenous creatinine clearance will be used to assess overall kidney function; and urine protein and the urine albumin-to-creatinine ratio will be used to assess the degree of kidney damage. An increase or maintenance of estimated glomerular filtration rate after the intervention, a decrease in serum creatinine, reductions in urine protein and the urine albumin-to-creatinine ratio, and improvement in endogenous creatinine clearance will be considered indicative of improved kidney function. The four components of the blood lipid profile and blood glucose will also be measured to evaluate the effects of exercise on metabolic status.

Secondary outcomes include physical function, exercise capacity, cardiorespiratory function, and quality of life. Body fat percentage will be measured to assess changes in body composition. Grip strength testing will assess muscle strength, with the maximum grip strength recorded. The 30-second chair stand test will assess lower-limb muscle strength and functional capacity, with the number of completed repetitions recorded. The 6-minute walk distance will assess overall exercise capacity, reflecting exercise endurance and daily

functional status. Vital capacity testing will assess respiratory function. A health survey will also be used to evaluate changes in quality of life, sleep, and mental health.
In addition, renal hemodynamic parameters and biomarkers related to inflammation, oxidative stress, and renal fibrosis will be assessed to further evaluate the effects of exercise on disease status and potential underlying mechanisms in patients with CKD. Renal hemodynamic parameters include renal blood flow, renal arterial peak systolic velocity, end-diastolic velocity, and resistive index. These measures will be used to assess renal perfusion and vascular resistance. Increased renal blood flow, improved blood-flow velocity, and a reduced resistive index after the intervention will indicate improved renal hemodynamic status. Inflammatory markers include C-reactive protein, tumor necrosis factor-alpha, interleukin-6, and interleukin-10 and will be used to assess inflammatory responses. Lower inflammatory marker levels will indicate an improvement in inflammatory status. Oxidative stress markers include malondialdehyde, superoxide dismutase, and glutathione peroxidase and will be used to assess oxidative damage and antioxidant capacity. Lower malondialdehyde levels and higher superoxide dismutase and glutathione peroxidase levels will indicate improvement in oxidative stress status. Renal fibrosis-related biomarkers include transforming growth factor-beta 1 and connective tissue growth factor. These markers will be used to assess changes in processes related to renal fibrosis, with lower levels suggesting that the progression of renal fibrosis may be inhibited.

Adverse Events and Potential Risks {17}

Before training and testing, participants' health status will be checked, and heart rate will be measured using a fitness band. Suitability for that day's training will also be assessed in accordance with advice from a physician or other qualified medical personnel. The training area must have a flat, unobstructed surface, and necessary first-aid supplies must be available.
Criteria for suspending or terminating training or testing on a given day include chest tightness or chest pain, marked shortness of breath, dizziness, blurred vision, unsteadiness while standing, markedly abnormal resting blood pressure or an abnormal increase in blood pressure during exercise, substantial physical pain, acute infection or fever, significant discomfort, a participant's request to stop, or a researcher's judgment that continuing the test would pose a risk. An adverse event is defined as any discomfort or injury occurring during

the study, including but not limited to dizziness, chest tightness, substantial pain, falls, sprains, muscle strains, abnormal blood pressure, and events requiring medical attention. All adverse events will be recorded, including the time and place of occurrence, severity, possible relationship to the intervention, management, and outcome. Serious adverse events will be reported promptly to the ethics committee.

This is a single-center exercise intervention trial conducted at the Health Management Center of Beijing Aerospace General Hospital, with risks considered generally manageable. Therefore, an independent data monitoring committee will not be established. A designated safety officer within the research team will periodically review attendance, adverse events, serious adverse events, protocol deviations, and withdrawals. Serious adverse events will be reported promptly to the ethics committee. The principal investigator, on-site medical staff, and ethics committee will jointly determine whether the relevant training should be suspended or terminated.

Participant Timeline {18}

The study process will be: recruitment and publicity → preliminary screening → informed consent → baseline assessment → randomization → multicomponent exercise intervention or routine health education at months 2, 4, 6, and 12 → post-intervention assessment → follow-up three months after the intervention ends → data organization and statistical analysis.

The participant timeline has been developed with reference to the recommended SPIRIT format and is presented in Table 2.

Table 2. Schedule of Enrollment, Interventions, and Assessments

Study activity or assessment	Screening	Baseline (T0)	Month 2 (T1)	Month 4 (T2)	Month 6 (T3)	Month 12 (T4)
Informed consent	✓					
Eligibility assessment	✓					
Demographic data collection		✓				
Medical history and medication records		✓	✓	✓	✓	✓
Randomization		✓				

Exercise intervention			✓	✓	✓	✓
Exercise adherence records			✓	✓	✓	✓
Adverse event monitoring		✓	✓	✓	✓	✓
6-minute walk test		✓	✓	✓	✓	✓
Grip strength test		✓	✓	✓	✓	✓
30-second chair stand test		✓	✓	✓	✓	✓
Vital capacity measurement		✓	✓	✓	✓	✓
Kidney function tests, including estimated glomerular filtration rate, serum creatinine, and urine albumin-to-creatinine ratio		✓	✓	✓	✓	✓
Blood lipid and blood glucose tests		✓	✓	✓	✓	✓
Inflammatory marker tests		✓	✓	✓	✓	✓
Oxidative stress marker tests		✓	✓	✓	✓	✓
Renal fibrosis-related marker tests		✓	✓	✓	✓	✓
Short Form-36 health survey		✓	✓	✓	✓	✓

Sample Size Estimation {19}

Previous randomized controlled trials of exercise interventions in patients with CKD have generally used small to moderate sample sizes, ranging from several dozen to more than one hundred participants. For example, Weiner and colleagues conducted a multicenter randomized controlled trial involving 99 patients with CKD. The intervention primarily involved aerobic exercise combined with strength training and evaluated the effects of long-term exercise training on 6-minute walk distance, physical function, and cardiorespiratory fitness, while also assessing estimated glomerular filtration rate, albuminuria, blood glucose, and body mass index. This study suggests that exercise interventions can be evaluated in trials with sample sizes approaching 100 participants.

Uchiyama and colleagues conducted a randomized controlled trial involving 46 patients with severe CKD. The intervention combined home-based aerobic exercise and resistance training, and the study evaluated exercise capacity, cardiorespiratory fitness, and health-related quality of life. Leehey and colleagues conducted a structured exercise randomized controlled trial involving 36 patients with CKD and coexisting obesity and diabetes, assessing exercise capacity, urine protein, kidney function, and inflammation-related markers. Hiraki and colleagues also conducted a randomized controlled exercise study involving 36 patients with CKD, evaluating the effects of home-based exercise on kidney function, grip strength, and lower-limb muscle strength. These studies suggest that sample sizes of approximately 20–30 participants per group are generally sufficient for evaluating exercise function, physical function, and kidney-related outcomes in exercise intervention studies involving patients with CKD. This study will include four groups: a control group, an aerobic exercise group, a resistance exercise group, and a combined exercise group. Based on a G*Power calculation using an alpha level of 0.05 and a beta level of 0.2, the estimated sample size is 26 participants per group. Allowing for a 20% dropout rate, the final target is 30 participants per group, for a total sample size of 120 participants.

Participant Recruitment {20}

Participants will be recruited primarily through the collaborating hospital and will be drawn from three populations. First, individuals identified through routine health examinations at the Health Management Center as having CKD stages G1 or G2 will be considered. Second, patients with CKD stages G3 or G4 diagnosed by the nephrology department who are receiving dietary management and basic pharmacological treatment and whose condition is relatively stable will be considered. Eligible individuals will be enrolled after providing informed consent. Third, recruitment notices will be disseminated through posters and various channels and relevant online platforms to recruit volunteers more broadly.
Intervention Allocation: Randomization

Sequence Generation {21a}

The random allocation sequence will be generated using computer-based random number generation by a researcher who is not involved in participant recruitment, intervention delivery, or outcome assessment, thereby keeping the randomization process independent of study implementation.

Method of Sequence Generation {21b}

Simple randomization will be used. A researcher will use the RAND function in Microsoft Excel to generate random numbers. After sorting the random numbers, eligible participants will be randomly assigned in a 1:1:1:1 ratio to the aerobic exercise group, resistance exercise group, combined exercise group, or control group.

Allocation Concealment Mechanism {22}

The random allocation sequence will be generated and retained by an independent researcher. After eligibility screening, informed consent, and baseline assessment have been completed, the study coordinator will assign

participants according to the random sequence. This process is intended to prevent researchers from predicting group assignments in advance during recruitment and baseline assessment.

Implementation of Randomization {23}

The research team will screen and recruit participants. An independent researcher will generate the random allocation sequence. After baseline assessment, another researcher will assign participants to groups according to the prespecified sequence and notify the intervention personnel so that the corresponding training can begin.
Blinding

Who Will Be Blinded {24a}

After group allocation, participants will be blinded to their group assignment as far as feasible. Personnel delivering the exercise interventions cannot be blinded. Outcome assessors and statistical analysts will be kept blinded to group assignments as far as possible.

How Blinding Will Be Achieved {24b}

Because the different exercise interventions involve different training content, separate WeChat groups and separate exercise communities in the Xiaodaka mini-program will be established according to randomization assignments to reduce information exchange between groups. The aerobic, resistance, and combined exercise groups will have separate WeChat groups and exercise check-in communities designated Exercise Group 1, Exercise Group 2, and Exercise Group 3, respectively. These groups will be used only for training notifications, exercise guidance, check-in records, and related information management for their assigned participants. Information will not be shared across groups, in order to reduce the dissemination of exercise programs and training content between groups.
During supervised, in-person exercise sessions, different groups will train at different times to reduce contact and communication between participants and minimize cross-group contamination. The schedule will be as follows: on one weekday afternoon, aerobic exercise will take place from 17:30 to 18:30 and resistance exercise from 18:40 to 19:40; on one weekend morning, aerobic exercise will take place from 09:00 to 10:00 and resistance exercise from 10:20 to 11:20; and every Saturday afternoon, aerobic exercise will take place from 14:00 to 15:00 and resistance exercise from 15:20 to 16:20.
All exercise intervention groups will attend at least one supervised, in-person session each week. The other two sessions will be completed remotely and recorded. In accordance with the training plan, participants in the combined exercise group may choose to attend aerobic or resistance exercise sessions according to their individual circumstances, or alternate between the two forms of training within the same week, to implement the combined exercise intervention. Researchers will use WeChat groups and the Xiaodaka mini-program to send exercise reminders, provide training guidance, record completion, and periodically summarize participation to support consistent implementation of the intervention protocols across groups.

Emergency Unblinding {24c}

If an assessor inadvertently becomes aware of a participant's group assignment, the unblinding event will be documented. Where possible, subsequent assessments will be conducted by another assessor who remains blinded.

Data Collection and Management

Plans for Assessment and Collection of Outcomes {25a}

Kidney function and metabolic parameters will be assessed at baseline and at each follow-up time point. Fasting venous blood and urine samples will be collected from participants within the specified time windows. Nurses from the hospital's Health Management Center will perform tests using standardized laboratory procedures. Serum creatinine will be used to calculate estimated glomerular filtration rate. Urine tests will include urine protein and the urine albumin-to-creatinine ratio, while collected urine will also be used to calculate endogenous creatinine clearance. Blood samples will additionally be used to measure the four components of the blood lipid profile and fasting blood glucose. All tests will follow hospital standard procedures and will be performed, analyzed, and documented by qualified laboratory personnel.

Body composition and physical function outcomes will be assessed at baseline and at each follow-up time point. Body fat percentage will be measured using an InBody body composition analyzer. Grip strength will be measured using a calibrated dynamometer, with results recorded according to a standardized testing procedure. Vital capacity will be measured using a standardized spirometer. The 30-second chair stand test will be performed according to a standardized procedure to assess lower-limb muscle strength and functional capacity. These assessments will be performed by researchers who have received standardized training and are not involved in delivering the exercise intervention, to reduce measurement bias and ensure consistency across time points.

The 6-minute walk test will be used to assess overall exercise endurance and functional capacity. The procedure will follow the Chinese Expert Consensus on the Clinical Standardized Application of the 6-Minute Walk Test. Testing will take place in a designated, flat, straight, and safe walking area within the hospital. The test will be conducted by trained researchers who are not involved in delivering the exercise intervention, to reduce measurement bias. Before testing, researchers will explain the procedures and precautions in detail and assess participants' current health status to confirm that they have no obvious dizziness, chest tightness, severe pain, acute infection, or other condition that would make exercise testing inappropriate.

During the test, participants will choose a walking speed according to their maximum tolerated capacity and aim to cover as much distance as possible while maintaining safety. They may slow down or briefly stop to rest as needed, but the timer will continue running. The total distance walked in six minutes will be recorded as the principal measure of exercise endurance and functional capacity. Heart rate, blood pressure, oxygen saturation, and perceived fatigue will be recorded before the test, immediately after the test, and during recovery. Any discomfort occurring during the test will also be documented. If chest pain, marked shortness of breath, dizziness, substantial gait instability, or another safety concern occurs, the test will be terminated immediately and the prespecified safety procedures will be followed.

A health survey will be used to assess health-related quality of life and mental health. Trained researchers will

guide participants in completing the questionnaire independently, and scores will be calculated and recorded using the standard scoring method. Assessments will be performed at baseline and at the prespecified follow-up time points. To reduce information bias, questionnaire assessors will not participate in delivering the exercise interventions.

Renal hemodynamic parameters will be measured at baseline and at each follow-up time point. Examinations will be performed by qualified hospital ultrasonographers according to a standardized procedure. Measurements will include renal blood flow, renal arterial peak systolic velocity, end-diastolic velocity, and resistive index. The same equipment and parameter settings will be used, and image acquisition and data recording will follow the prespecified procedures. Personnel conducting the ultrasound examinations will not be involved in delivering the exercise intervention and will remain blinded to group assignments to reduce measurement bias.

Inflammatory markers will be assessed at baseline and at each follow-up time point using blood samples collected at the prespecified visits. These markers will include C-reactive protein, tumor necrosis factor-alpha, interleukin-6, and interleukin-10. Blood samples will be managed according to standardized collection, processing, storage, and transport procedures and analyzed in the laboratory to evaluate the effects of different exercise modalities on inflammatory responses.

Oxidative stress markers will be assessed at baseline and at each follow-up time point using blood samples collected at the prespecified visits. These markers will include malondialdehyde, superoxide dismutase, and glutathione peroxidase. Samples will be processed and stored according to standardized laboratory procedures, and the markers will be measured using standardized methods to preliminarily evaluate the effects of different exercise modalities on oxidative stress.

Renal fibrosis-related markers will be assessed at baseline and at each follow-up time point using blood samples collected at the prespecified visits. These markers will include transforming growth factor-beta 1 and connective tissue growth factor. Validated laboratory methods will be used, and testing will follow standardized sample processing and quality-control procedures to preliminarily investigate the potential effects of different exercise modalities on biological processes related to renal fibrosis.

Exercise adherence, training completion, and adverse events will be recorded throughout the study. Adherence will be evaluated primarily through attendance, training completion, and actual participation. Reasons and circumstances will be recorded when participants fail to complete or interrupt training. Exercise-related adverse events will be monitored throughout the study, including symptoms occurring during or after exercise, exercise-related injuries, and other events requiring medical attention. All adverse events will be documented, including the time of occurrence, presentation, severity, management, and outcome, and will be reported and managed according to the study protocol. These records will contribute to the overall assessment of the safety, effectiveness, and feasibility of different exercise modalities.

All outcome assessors will receive standardized training before the study begins and will follow prespecified standard operating procedures for measurements and data recording. Where possible, the same trained personnel will use the same equipment, testing conditions, and standardized forms at each time point. Laboratory samples will be managed according to standardized collection, processing, storage, and testing procedures, and functional assessments will follow standardized testing protocols. Outcome assessors will not participate in delivering the exercise interventions, to minimize measurement bias and support the comparability

and reliability of data collected at different follow-up time points.

Plans to Promote Participant Retention and Complete Follow-up {25b}

The research team will promote follow-up completion through assessment appointments, staggered assessment times, rest periods when necessary, staff-assisted reminders, follow-up telephone calls, and simplified feedback on results. Even if participants do not complete all training sessions, the research team will make every effort to collect primary outcome and safety outcome data at the different study stages.

Data Management {26}

Each participant will be assigned a unique study identification number, and personal identifying information will be stored separately from study data. All paper records will be kept by designated personnel, and electronic data will be stored on encrypted devices. Two researchers will independently enter the study data and cross-check the entries. Before analysis, the data will be checked for missing values, outliers, and logical errors. Intervention providers will be exercise intervention personnel or research team members who have received standardized training. Before training begins, they must be familiar with the study intervention manual, safety stopping criteria, RPE recording, exercise modification procedures, and adverse event recording procedures.

Confidentiality {33}

Each participant will be assigned a unique study identification number, and personal identifying information will be stored separately from study data. All paper records will be kept by designated personnel, and electronic data will be stored on encrypted devices. Publications will report only aggregated statistical results and will not contain any personally identifiable information.

Statistical methods

Statistical methods for primary and secondary outcomes {27a}

Excel will be used for data organization and preliminary checking. After the data have been verified, SPSS version 22.0 and GraphPad Prism will be used for statistical analyses and graphical presentation, as appropriate.

Normally distributed continuous variables will be summarized as means and standard deviations. Between-group comparisons will be performed using independent-samples t-tests, and within-group pre- and post-intervention comparisons will be performed using paired t-tests. Continuous variables that do not follow a normal distribution will be summarized as medians and interquartile ranges. Between-group comparisons will be performed using the Mann–Whitney U test, and within-group pre- and post-intervention comparisons will be performed using the Wilcoxon rank-sum test. Categorical variables will be summarized as frequencies and percentages and compared between groups using the chi-square test. Data collected at different time points will be analyzed using repeated-measures analysis of variance. A P value of less than 0.05 will be considered statistically

significant.

Who will be included in each analysis {27b}

The primary analysis will follow the intention-to-treat principle. All randomized participants with available or imputable data will be included and analyzed according to their originally assigned groups. Participants who complete at least 70% of the training sessions and complete the primary outcome assessments will also be included.

How missing data will be handled in the analysis {27c}

The primary outcome measures will be analyzed using linear mixed-effects models, incorporating all available data under the assumption that the missing data are missing at random. The reasons for missing data and the proportion of missing observations will be recorded and reported. If the proportion of missing data for a primary outcome exceeds 10%, multiple imputation will be used for sensitivity analysis.

Methods for additional analyses (e.g. subgroup analyses) {27d}

Correlation analyses will be conducted to examine the relationships between changes in primary and secondary outcome measures following exercise intervention and changes in related biological markers. Primary outcome measures include eGFR, serum creatinine, urine protein, UACR, endogenous creatinine clearance, and metabolic parameters. Secondary outcome measures include the 6-minute walk distance, grip strength, the 30-second chair stand test, and vital capacity.

Further analyses will examine the correlations between changes in these outcome measures and changes in renal hemodynamic parameters, inflammatory markers, oxidative stress markers, and renal fibrosis-related biomarkers. Renal hemodynamic parameters include renal blood flow, renal arterial peak systolic velocity, end-diastolic velocity, and the resistive index. Inflammatory markers include C-reactive protein, tumor necrosis factor-alpha, interleukin-6, and interleukin-10. Oxidative stress markers include malondialdehyde, superoxide dismutase, and glutathione peroxidase. Renal fibrosis-related biomarkers include transforming growth factor-beta 1 and connective tissue growth factor.

Where necessary, multiple linear regression models will be used to adjust for age, sex, baseline renal function, and other potential confounding factors, in order to further explore factors associated with improvements in renal function and physical function among participants with chronic kidney disease following different exercise modalities.

Interim analyses {28b}

No formal interim analysis of intervention efficacy is planned, and no early termination rule based on intervention efficacy will be established. Given the relatively long intervention period, the research team will conduct one interim safety review after participants have completed approximately 50% of the scheduled follow-up assessments. This review will focus on exercise-related adverse events, participant adherence, and implementation of the study protocol and will not serve as a basis for early study termination.

If a serious adverse event potentially related to exercise occurs, or if similar adverse events are found to cluster

substantially during the study, the research team will assess whether continuing the intervention may increase risks to participants. If necessary, the relevant exercise training will be suspended and a safety assessment conducted. The ethics committee will be consulted when appropriate, and the study protocol may be revised or the study terminated early if warranted.

Protocol and statistical analysis plan {5}

The statistical analysis plan is incorporated into the Statistical Analysis section of this protocol.

Oversight and monitoring

Composition of the coordinating centre and trial steering committee {3d}

The principal investigator and research team will be responsible for the overall organization and coordination of the study, including participant recruitment, randomization, delivery of exercise interventions, researcher training, quality control, data management, and safety monitoring.
The principal investigator will oversee implementation of the study protocol. Site researchers will be responsible for participant screening, intervention delivery, follow-up, and outcome assessments. Data management personnel will be responsible for data entry, verification, and database maintenance. Designated statistical personnel will conduct the statistical analyses.
This is a single-center study; no independent trial steering committee will be established. The research team will hold regular meetings to review and discuss study progress, data quality, and participant safety.

Composition of the data monitoring committee, its role and reporting structure {28a}

This is a single-center exercise intervention trial. The centralized exercise intervention site is the Health Management Center of Beijing Aerospace General Hospital, and the overall intervention risk is considered manageable. Therefore, no independent data monitoring committee will be established.
A designated safety officer within the research team will periodically review training attendance, adverse events, serious adverse events, protocol deviations, and participant withdrawals. Serious adverse events will be reported promptly to the ethics committee. The principal investigator, on-site medical personnel, and ethics committee will jointly determine whether the relevant training should be suspended or terminated.

Frequency and plans for auditing trial conduct {29}

The research team will periodically review training records, attendance records, adverse event records, protocol deviation records, and data completeness. If missing data, outliers, or deviations from the study protocol are identified, the reasons will be documented and corrective action will be taken promptly.

Protocol amendments {31}

Protocol version: Version 2.0, dated October 18, 2026.
If substantial changes are made to the study objectives, primary outcomes, sample size, randomization method, core intervention components, statistical analysis plan, or safety management procedures, a new protocol

version will be prepared. The content, rationale, and date of each amendment, together with the relevant ethics approval or filing status, will be documented. All substantial amendments will be implemented only after approval by, or filing with, the ethics committee, as applicable. The trial registration information will be updated accordingly.

Dissemination policy {8}

Upon completion of the study, the research team will prepare the results in accordance with the CONSORT statement and relevant intervention reporting guidelines. The main findings will be disseminated through updates to the trial registry, publication in peer-reviewed journals, presentations at academic conferences, and internal institutional reports.

The research team will provide participants and their family members with an accessible summary of the overall study results. No personally identifiable information will be disclosed.

Discussion

The main strengths of this study are as follows. First, the randomized controlled design allows direct comparison of different exercise modalities in participants with chronic kidney disease and may help clarify their relative benefits. Second, the study assesses not only conventional renal function parameters but also physical function and biological markers, enabling exploration of potential mechanisms from multiple perspectives. Third, the exercise programs allow appropriate individualThis study aims to evaluate the effects of different exercise interventions on renal function and overall health among participants with chronic kidney disease through a randomized controlled trial comparing the effects of different exercise modalities. Repeated follow-up assessments will be used to investigate the time windows and time-dependent patterns of exercise intervention effects. Molecular and biological techniques will be used to preliminarily explore the biological mechanisms potentially associated with the effects of different exercise modalities on chronic kidney disease, providing experimental evidence for understanding the biological mechanisms underlying exercise as an approach to chronic kidney disease prevention and management.

The primary outcome measures, including eGFR, serum creatinine, urine protein, UACR, and endogenous creatinine clearance, will be used to assess changes in renal function. The four components of the blood lipid profile and fasting blood glucose will be used to evaluate changes in metabolic status following exercise intervention. Secondary outcome measures, including the 6-minute walk distance, grip strength, the 30-second chair stand test, vital capacity, and health survey scores, will be used to assess changes in exercise capacity, physical function, and quality of life. Renal hemodynamic parameters, inflammatory markers, oxidative stress markers, renal fibrosis-related biomarkers, and renal injury-related markers will also be assessed to further investigate the biological processes potentially associated with improvements in renal function and overall health following different exercise modalities.

If the results indicate that exercise intervention improves exercise capacity, physical function, or kidney-related parameters in participants with chronic kidney disease, the findings may provide further evidence supporting

exercise as part of comprehensive chronic kidney disease management. Based on differences in the effects of different exercise modalities, future exercise prescriptions may be tailored to disease stage, physical function, and exercise tolerance. For example, aerobic exercise may be more suitable for improving cardiorespiratory endurance and metabolic status, resistance exercise may be more beneficial for improving muscle strength and functional capacity, and combined exercise may offer potential advantages for improving overall functional recovery. Future studies could further investigate the effects of long-term exercise interventions on kidney disease progression, cardiovascular risk, and quality of life.

adjustments based on participants' baseline conditions while maintaining standardized core principles, supporting clinical feasibility. Fourth, recording training completion, exercise intensity, and adherence will enable further evaluation of intervention implementation.

This study also has several limitations. First, the intervention duration and sample size are limited. The study is primarily designed to evaluate changes in functional status and related parameters following different exercise modalities. One year may be insufficient to observe long-term chronic kidney disease progression events, such as sustained declines in renal function or the development of end-stage kidney disease. Second, most participants will be recruited from patients attending the Health Management Center of Beijing Aerospace General Hospital, people working in nearby organizations, and local residents. The study may therefore be subject to geographical limitations, and its findings will require further validation in other regions and in populations with different disease characteristics. Third, because of the nature of exercise interventions, participants and intervention personnel cannot be blinded, potentially introducing behavioral changes and expectancy effects. Fourth, differences in training duration, exercise load, and participant adherence across exercise modalities may affect the interpretation of intervention effects. Fifth, inflammatory, oxidative stress, and renal fibrosis-related markers are primarily intended to explore potential mechanisms. The findings will not directly establish causal relationships, and further validation in larger, multicenter studies with longer follow-up will be required.

Trial status

Protocol version: Version 2.0, dated October 18, 2026.

Recruitment is planned to begin in 2026, with recruitment expected to be completed in June 2026. The first post-intervention assessment is scheduled for September 2026, the second for November 2026, and the third for January 2027. Post-intervention measurements are scheduled for July 2027, and data organization and reporting are expected to be completed in October 2027.

Study phase	Main activities	Dates
Preparation	Literature review, finalization of the protocol, ethics application, researcher training, identification of a suitable exercise venue, and participant recruitment preparation	April 1, 2026–June 1, 2026
Recruitment and baseline assessment	Hospital-based recruitment, screening,	June 26, 2026–July 14, 2026

	informed consent, and T0 measurements	
Intervention phase	Exercise interventions in the different groups and health education for the control group, with assessments at 2, 4, 6, and 12 months	July 20, 2026–July 20, 2027
Post-intervention assessments and follow-up	T1, T2, T3, and T4 assessments and follow-up at scheduled time points	July 20, 2027–October 20, 2027
Data management and reporting	Data cleaning, statistical analysis, interpretation of results, and manuscript preparation	October 21, 2027–December 26, 2027

Abbreviations

Abbreviations	Meanings
CKD: Chronic kidney disease	CKD: Chronic kidney disease
eGFR: Estimated glomerular filtration rate	eGFR: Estimated glomerular filtration rate
ITT: Intention-to-treat	ITT: Intention-to-treat
RPE: Rating of perceived exertion	RPE: Rating of perceived exertion
UACR: Urine albumin-to-creatinine ratio	UACR: Urine albumin-to-creatinine ratio
HRmax: Maximum heart rate	HRmax: Maximum heart rate

Declarations

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The research team thanks all medical and nursing staff at the Health Management Center of Beijing Aerospace General Hospital for their support with participant recruitment, health assessments, biological sample collection, and follow-up management. The team also thanks all participants for their understanding, trust, and active cooperation. In addition, the team acknowledges the contributions of research team members to exercise intervention delivery, data collection, quality control, and study coordination, which support the implementation of this study.

Authors' contributions {3a}

The study will be conducted collaboratively by the research team. The principal investigator will be responsible for study design and quality control. Researchers will conduct participant screening and recruitment, deliver exercise interventions, and perform outcome assessments. Data management personnel will be responsible for data entry, verification, and storage. Statistical personnel will conduct the statistical analyses.

Sources of funding and other support {7a}

This study is funded by the Basic Research Operating Expenses of the China Institute of Sport Science, General Administration of Sport of China. The funder will not participate in study design, data collection, statistical analysis, interpretation of results, or manuscript preparation. The research team declares no conflicts of interest related to this study.

Availability of data and materials {6}

The original study data are not planned to be publicly shared. The data will be used by the research team only for analyses related to this study, quality control, verification of results, and publication, within the scope of ethics approval and informed consent. Only aggregated statistical results will be reported in publications, without information that could identify individual participants.

Ethics approval and consent to participate {30}

This study will be conducted in accordance with the relevant principles of the Declaration of Helsinki. Approval from the ethics committee will be obtained before the study begins. All participants will sign written informed consent forms after receiving sufficient information about the study objectives, procedures, potential benefits, and risks. Participants may withdraw from the study at any time without conditions. Study data will be used for research purposes only, and no personally identifiable information will be included in published results. Substantial protocol amendments will be implemented only after the required ethics approval and the trial registration information will be updated accordingly.
Ethics committee: Science and Technology Ethics Review Committee of the China Institute of Sport Science, General Administration of Sport of China.
Ethics approval number: CISS20250814.

Consent for publication

Not applicable. This study protocol does not include identifiable images, videos, or individual participant information. If any identifiable materials are included in future publications, separate written consent for publication will be obtained.

Competing interests {7b}

The research team declares no conflicts of interest related to this study.

Authors' information

Not applicable.

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