

BMJ Open Effects of resistance training combined with balance training on physical function among older adults: a protocol for a randomised controlled trial

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ABSTRACT

Introduction The world's population is ageing. Age-related declines in physical function negatively affect the quality of life but may be ameliorated by certain types of exercise. The purpose of this study is to investigate the effects of combining resistance training (RT) with balance training on physical function in older community-dwelling adults to provide a reference for this type of exercise compared with other exercises and to provide a theoretical basis for optimising exercise plans to improve physical function among older adults.

Methods This single-blind randomised controlled trial will recruit 66 community dwelling adults 60–89 years of age with normal cognition. Participants will be randomly assigned to one of three groups: RT, RT combined with balance training or a control group with usual daily activities. Exercise interventions will be conducted in three 45 min sessions per week for 24 weeks. Primary physical function outcomes will be assessed using the timed up and go test, usual walking speed, maximal walking speed, 30 s chair stand and 30 s arm curl. Secondary assessments will be conducted using the 2 min step test, back scratch test and chair sit-and-reach test. All physical function assessments will be performed at baseline and after 12 and 24 weeks of exercise interventions. Exercise intensity will be monitored to maintain moderate intensity by heart rate, ratings of perceived exertion and OMNI-Resistance Exercise Scale. Data that conform to a normal distribution will be expressed as means±SD, otherwise as medians and interquartile intervals. Pretest, mid-test and post-test outcomes will be analysed for within-group and between-group comparisons using two-way repeated measures analyses of variance.

Ethics and dissemination This proposal was reviewed and approved by the Shanghai University of Sport Research Ethics Committee (102772021RT067). The results will be disseminated to the trial participants and as a peer-reviewed publication.

Trial registration number ChiCTR2200056090.

INTRODUCTION

With the progress of ageing in the world, prolonging healthy life expectancy is a key concern for governments. Population ageing not only brings economic, pension and healthcare burdens to families and society

STRENGTHS AND LIMITATIONS OF THIS STUDY

- ⇒ Provides a targeted programme of resistance training combined with balance training that specifically addresses physical function decline among older adults.
- ⇒ Physical function measurements are comprehensive and allow for a multidimensional understanding of the effects of exercise programmes on physical function in older adults.
- ⇒ Despite the overall length of the exercise intervention (12–24 weeks) having the potential to lead to high study attrition, the use of OMNI-Resistance Exercise Scale to monitor the intensity of the exercise intervention is tolerable and enjoyable for older adults, which are important factors in determining their continued participation in the study.
- ⇒ The intervention group will have more contact time with healthcare workers than the control group.

but also directly reduces the quality of life of the elderly due to age-increasing ageing. Physical function is a growing concern because it is critical to the quality of life^{1 2} and is an important component of health and well-being in older adults.³ Decreased physical function is strongly associated with the onset of disability and mortality.⁴ Physical function refers to the ability to perform simple and complex activities in daily life. In an ageing society, more research is needed to better understand the factors that can help older adults maintain physical function to extend healthy life expectancy.⁵

Currently, there are no effective medications for slowing the decline of physical function, and exercise training is an important strategy to benefit physical function.^{6 7} In resistance training (RT) combined with balance training (RBT), resistance exercise is performed on an unstable support surface or using multiplane modes. For most studies^{8–11} examining this type of training, participants performed resistance and balance training



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simultaneously, with only a few studies assessing balance and RT alternated during the week¹² or integrating RBT into the daily life of older adults,¹³ both of which delayed muscle loss or improved muscle strength and balance. All of these afore-mentioned studies provided insight for the design of this proposed study.

However, there are relatively few studies in this area, and the intervention programmes used vary greatly. For example, the health status for the intervention populations varied (healthy,^{10,13} frail¹⁴ and fallen¹⁵) and different assessment indexes were used, leading to a high level of heterogeneity among the studies and making it difficult to form a unified conclusion and consensus. Thus, we designed this randomised controlled trial to investigate the effects of RBT on physical function in older adults with standard levels of cognition. This study will provide an evidence-based foundation for optimising exercise programmes and healthy ageing among older adults.

METHODS

Study design

This experimental protocol is for a prospective, single-blind randomised controlled trial to evaluate effects of RBT on older adults in dynamic balance and functional mobility, walking speed, upper and lower body muscle strength and flexibility. The study follows the Standard Protocol Items: Recommendations for Interventional Trials statement guidelines.¹⁵ Older adults eligible for the experiment will be randomly and equally assigned to one of three groups: RT, RBT and the control group. A 24-week exercise intervention will be performed. The Montreal Cognitive Assessment (MoCA) will be conducted and evaluated before the exercise intervention begins. Physical function tests will be performed and evaluated before (baseline) and 12 and 24 weeks after the exercise intervention (figure 1). It will begin on 1 March 2022 and run through 1 March 2024.

Participants

This study will rely on the community of Kongjiang Road, Yangpu District, Shanghai to recruit subjects through self-media, posters and community outreach. Inclusion criteria include individuals (1) 60–89 years of age and (2) with cognitive abilities are within normal standard reference ranges as assessed by the MoCA. The Chinese version of the MoCA will be used to assess global cognition, which will be evaluated by uniformly trained psychology researchers. The cut-off points for a score considered within cognitively normal reference ranges in this study will be based on previously developed division boundaries for older adults in Chinese communities: >13 for people who are illiterate, >19 for people with an elementary school education and >24 for people with junior high school or higher educational level.¹⁴ The MoCA has sensitivity (80%–100%) and specificity (50%–76%) in identifying mild cognitive impairment.¹⁶ Older adults with normal cognition will be screened according to the above

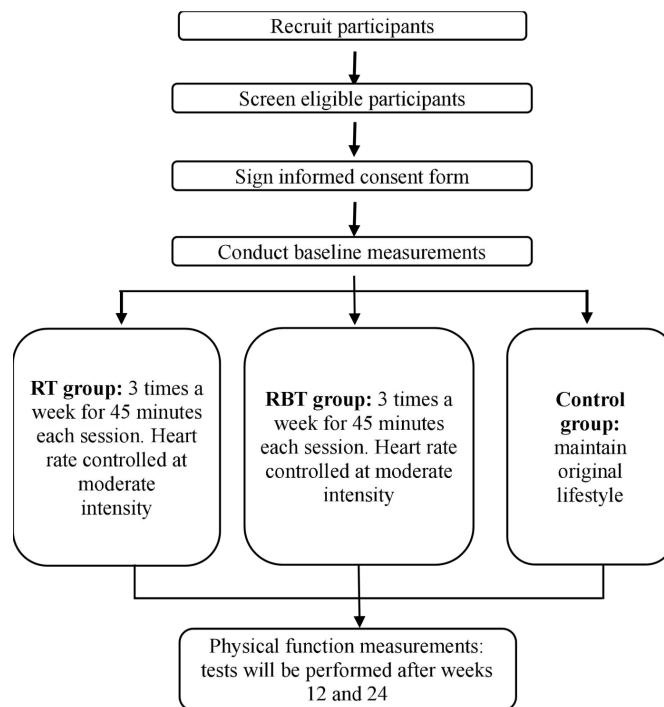


Figure 1 Flowchart of study design. RBT, resistance training combined with balance training; RT resistance training.

criteria and three additional inclusion criteria: (1) ability to communicate normally and to independently complete the tests designed for this study; (2) no significant gait impairment or mental illness; and (3) no regular exercise habits. The exclusion criteria are as follows: (1) cognitive impairment; (2) inability to independently complete the tests used in this study; (3) difficulty walking (due to, for example, taking drugs that affect balance, such as diuretics and glucose-lowering drugs); (4) severe diabetic complications; (5) uncontrolled hypertension; (6) presence of a prosthesis or pacemaker; (7) psychiatric disorders; and (8) regular exercise habits. Participation in this study will be voluntary. This proposal was reviewed and approved by the Shanghai University of Sport Research Ethics Committee (102772021RT067).

Sample size

The sample size was calculated using G*Power, V.3.1.9.7, software to be at least 54 people based on previous relevant studies,¹¹ an alpha of 0.05 with power (1– β) of 0.80, and allowing for a 20% attrition rate. Therefore, we will recruit 66 older adults, 22 participants per group.

Randomisation

Older adults who volunteer to participate in the study will be screened for eligibility and then randomly and equally assigned to RT, RBT or the control group. We will use Excel software to code the 66 participants sequentially based on their enrolment time, and then use the formula ‘=RAND ()’ to generate the corresponding random sequence. The 66 participants will be sorted and grouped using the random sequence. Randomisation will be performed by professional information technology

Table 1 Resistance training program⁵⁸

Exercise type	Week of exercise intervention					
	1–2* (Pro. A)	3–7* (Pro. B)	8–12† (Pro. C)	13–17† (Pro. D)	18–22† (Pro. E)	23–24‡ (Pro. F)
Warm-up	10 min	10 min	10 min	10 min	10 min	10 min
High step in place§	2×30 s	2×30–60 s	2×30–60 s	3×30–60 s	3×30–90 s	3×60–120 s
Standing heel raises¶	2×8–12	2×10–15	2×10–15	3×10–15	3×10–20	3×15–20
Chair sitting and standing¶	2×8–12 (47 cm)	2×10–15 (47 cm)	2×10–15 (43 cm)	3×10–15 (43 cm)	3×10–20 (40 cm)	3×15–20 (40 cm)
Half squat§	2×30 s	2×30–60 s	2×30–60 s	3×30–60 s	3×30–90 s	3×60–120 s
Half squat lateral walk¶	2×8–12	2×10–15	2×10–15	3×10–15	3×10–20	3×15–20
Squat with bicep dumbbell curl (women 2.5 kg, men 4.0 kg)¶	2×8–12	2×10–15	2×10–15	2×10–15	2×10–20	2×15–20
In-place lunge¶	2×8–12	2×10–15	2×10–15	3×10–15	3×10–20	3×15–20
Relaxed stretching	5 min	5 min	5 min	5 min	5 min	5 min

*Movement tempos: concentric 3 s and eccentric 3 s.

†Movement tempos: concentric 2 s and eccentric 4 s.

‡Movement tempos: concentric as fast as possible and eccentric 3 s.

§Multiplication refers to the amount of time spent.

¶Multiplication refers to the number of times the indicated repetitions are repeated.

staff to ensure that the study researchers are unaware of participant recruitment and grouping.

Exercise intervention

The exercise intervention will last a total of 24 weeks. The participants will be randomly assigned to one of three groups: RT (table 1), RBT or the control group of usual daily activities. The RT and RBT exercise interventions will be conducted in three sessions per week for 45 min each session for 24 weeks. The exercise intervention will be conducted in groups of five or six people with a total of four groups.

The proposed RT programme is provided in table 1. The RBT programme is based on the RT programme. RBT is achieved by adjusting the vertical vibration platform (figure 2) to provide an unstable plane for RT. Increasing the vibration amplitude by selecting a higher setting (from 1 to 7) on the remote control causes the plane to become more unstable. For safety, the vertical vibration platform has a guardrail surrounding it. The control group will maintain their original lifestyle and will be interviewed every 2 weeks about any lifestyle changes. The specific intervention methods can be seen in table 2.

Exercise intensity will be monitored to maintain moderate intensity by heart rate (Polar Heart Rate Monitor), subjective ratings of perceived exertion (RPE) and OMNI-Resistance Exercise Scale (OMNI-RES).¹⁷ The heart rate range during exercise will be controlled to 40%–59% of the reserve heart rate. The heart rate reserve is equal to the maximum heart rate ($207 - 0.7 \times \text{age}$) minus the resting heart rate. The RPE has a range of 11–13 levels, from ‘relaxed’ to ‘some effort’. The RT and RBT exercise interventions will use the OMNI-RES monitoring of exercise intensity. The OMNI-RES will be visible to

participants at all times. The session rating of perceived exertion (s-RPE) will be used as a marker for the physical and mental responses to each training stage. Individuals participating in RT will start with the same training session (ie, protocol A). The main purpose of the first training session will be to familiarise the participants with the structure of the training session to allow them to focus on mastering the correct technical movements. In the next training session, the exercise load will be adjusted



Figure 2 The vertical vibration platform and matching remote control. The figure was created by the authors of this paper.

Table 2 Intervention overview

Item no.	Brief name	Group		
		RBT group	RT group	Control group
1	Why	Resistance training combined with balance training.	Resistance training.	Control.
2	What	24 weeks of supervised and guided exercise intervention.		Maintain their original lifestyle.
3	What (materials)	45 min exercise, 3 times/week.		Usual daily activities; interviewed every 2 weeks about any lifestyle changes.
4	What (procedure)	Assessments will be performed at baseline and after 12 and 24 weeks of exercise interventions. The results of the proposed trial will be made available to each of the participants and their families in a timely manner.		
5	Who provided	The coaches and assistant coaches are graduate students in physical education and training. The assessment is conducted by doctoral students from Shanghai University of Sport PhD students.		Interviews performed by Shanghai University of Sport PhD students majoring in physical education and training.
6	How	Exercise interventions will take place in dedicated exercise spaces. Exercise instruction will be delivered via face to face.		The interviews will be conducted mainly face to face, combined with telephone interviews.
7	Where	Exercise interventions are conducted at the Community Health and Exercise Home for Seniors, which is a professional exercise centre for seniors.		The visit will take place in the meeting room of the Community Health and Exercise Home for Seniors.
8	When and how much	Table 3 shows the RT programme. The RBT programme is based on the RT programme. RBT is achieved by adjusting the vertical vibration platform (figure 2) to provide an unstable plane for resistance training. Increasing the vibration amplitude by selecting a higher setting (from 1 to 7) on the remote control causes the plane to become more unstable. For safety, the vertical vibration platform has a guardrail surrounding it.		Interviews, 10–15 min.
9	Tailoring	Exercise intensity will be monitored to maintain moderate intensity by heart rate (Polar Heart Rate Monitor), subjective ratings of perceived exertion and OMNI-Resistance Exercise Scale.		
10	How well	The results of the proposed trial will be made available to each of the participants and their families in a timely manner so that they may better understand their health status and perhaps increase their confidence in evidence-based exercise.		

RBT, resistance training combined with balance training; RT, resistance training.

according to each individual's s-RPE from the previous training session. If the value of s-RPE was 5 or below (ie, moderate), the load will be increased (eg, from protocol A to protocol B; from protocol B to protocol C). If the value of s-RPE is 6–8 (ie, hard), the load will remain the same in the next training session. If a participant's s-RPE value is 9 for two consecutive training sessions (even for the lowest load protocol, that is, protocol A), the number of sets of exercises will be reduced by one in the next training session and so on until the individual has only one set per training session.¹⁸ Participants will be asked about their feelings (and their responses recorded) during the middle of each set, at the end of the centric phase of the last repetition, and within 15 min after the end of the entire exercise. There will be a rest interval of 60–120 s between sets of exercises.

Each session will be monitored by three personnel (one coach, one assistant coach and one medically qualified healthcare worker). The coaches and assistant coaches

are graduate students in physical education and training. The medical and nursing staff are from community hospitals. Coaches and assistant coaches will be responsible for movement teaching and instruction as well as exercise load monitoring, and healthcare personnel will be responsible for exercise intensity monitoring and medical supervision and guidance before, during and after exercise. Exercise attendance, heart rate during exercise and the type of exercise will be recorded. If participants are absent, they will be scheduled for additional training at another time. The assessment is conducted by doctoral students from Shanghai University of Sport PhD students.

VARIABLES

Sociodemographic and confounding variables

Participants will be invited to take part in face-to-face interviews to answer a questionnaire and to take the Chinese version of the MoCA. The questionnaire includes age,

Table 3 Participant sociodemographic and confounding variables

Characteristic	Group		
	Resistance	Resistance+balance	Control
Age (years)			
Gender (female/male)			
BMI (kg/m ²)			
Educational level			
Physical activity level			
Chronic condition			
Hypertension			
Diabetes			
Hyperlipidaemia			
Heart disease			
MoCA Score			

BMI, body mass index; MoCA, Montreal Cognitive Assessment.

gender, weight, height, educational level and whether the participant has a history or received a physician's diagnosis of hypertension, diabetes, hyperlipidaemia or heart disease (table 3). Body mass index is height (m) divided by weight (kg) squared. Confounding variables will include age, gender, weight, height, educational level, hypertension, diabetes, hyperlipidaemia and heart disease.

Primary outcome

The primary outcome of physical function will be measured by using the timed up and go test (TUG), usual walking speed (UWS), maximal walking speed (MWS), 30s chair stand test (30s CST) and 30s arm curl test (30s ACT) (table 4). The TUG will be used to measure dynamic balance and functional mobility and is a sensitive (sensitivity=87%) and specific (specificity=87%) indicator for identifying older adults who are prone to falls.¹⁹ Participants will stand up from a chair with the seat at a height of 43 cm, walk forward at their usual pace, turn around an obstacle 3 m in front of them and return to sit on the chair. The process is considered one repetition, and the time spent completing the task will be recorded. The mean of the time required to complete two repetitions to the nearest 0.01 s will be used for analyses. The 6 m walk test is a common method used for assessing walking speed.²⁰ A stopwatch will be used to record the time needed to walk the 6 m between a 2 m marker and an 8 m marker in order to avoid the effect of a starting acceleration in the first 2 m and a braking deceleration in the last 2 m. Robertson *et al*¹⁷ have shown that a handheld stopwatch is as reliable as an automatic timer when measuring walking speed. The two separate measurements of UWS and MWS will be each averaged to an accuracy of 0.01 s. The final walking speed will be calculated as 6 m divided by the time taken. The walking speed is accurate to 0.01 m/s¹. The 30s ACT will be used to assess upper body muscle strength. The test will be performed with the participant sitting on a chair with the

seat at a height of 43 cm, feet flat on the ground, with the dominant hand fully extended downward and holding a dumbbell (3.6 kg for men and 2.3 kg for women) in a preparatory motion. The participant will raise and lower the dumbbell, and the number of repetitions performed in 30 s will be recorded. The 30s CST will be used to assess lower extremity muscle strength and power. The test will be performed with the participant sitting on a chair with a seat at a height of 43 cm, with both arms crossed in front of the chest, chest up, head up, back against the back of the chair and feet shoulder-width apart. The participants will rise to a full standing position and then return to a full seated position. Standing to sitting is recorded as a single repetition, and the total number of repetitions completed in 30 s, monitored using a stopwatch, will be recorded.

Secondary outcomes

Secondary indicators for the proposed study will include the 2 min step test (2m ST), back scratch test (BST) and chair sit-and-reach test (CSRT) (table 4). The 2min ST will be used to assess aerobic endurance. The number of full steps completed in 2min, with each knee raised to a point midway between the patella and iliac crest, will be assessed. The score for the test will be the number of times the right knee reaches the required height. The BST will be used to assess upper body (shoulder) flexibility. The test will be administered with one of the participant's hands extended over the shoulder and the other hand extended up to the middle of the back, with the distance (in centimetres) between the extended middle fingers recorded. The CSRT will be used to evaluate lower body flexibility. The test will be performed with the participant sitting on the front of a chair with the legs extended and the hands reaching towards the toes. The distance in centimetres between the extended fingers and the tips of the toes will be recorded.

**Table 4** Outcome variables

Variables	Groups	Baseline	12 weeks	24 weeks	F(P) Main effect of group	F(P) Main effect of time	F(P) Interaction of group×time
TUG	Control						
	RT						
	RBT						
UWS	Control						
	RT						
	RBT						
MWS	Control						
	RT						
	RBT						
30 s CST	Control						
	RT						
	RBT						
30 s ACT	Control						
	RT						
	RBT						
2 min ST	Control						
	RT						
	RBT						
BST	Control						
	RT						
	RBT						
CSRT	Control						
	RT						
	RBT						

30 s ACT, 30 s arm curl test; BST, back scratch test; CSRT, chair sit-and-reach test; 30 s CST, 30 s chair stand test; MWS, maximal walking speed; RBT, resistance training combined with balance training; RT, resistance training; 2 min ST, 2 min step test; TUG, timed up and go test; UWS, usual walking speed.

All physical function outcome indicators will be measured at baseline and after 12 and 24 weeks of exercise intervention. The specific outcome variables are shown in [table 4](#).

Patient and public involvement

In 2021, prior to the development of this study protocol, we conducted a study with an exercise intervention programme designed to improve physical function, and the study included a group discussion. Participants were older community-dwelling adults. The aims were to investigate whether older adults were interested in RT, or balance training, or both to improve their physical function and to reduce falls, and to ascertain why they were or were not interested in such training. In designing the interventions for use in this study protocol, we took into account the information obtained during those group discussions to meet the needs of older adults while ensuring a safe and effective exercise intervention. The results of the proposed trial will be made available to each

of the participants and their families in a timely manner so that they may better understand their health status and perhaps increase their confidence in evidence-based exercise.

Statistical analysis

Data analyses will be conducted using SPSS, V.25.0, software. Test data will be assessed for normality, and data that conform to a normal distribution will be expressed as the mean±SD. Data that do not conform to a normal distribution will be described by the median and interquartile intervals. Pretest, mid-test and post-test outcomes will be analysed for within-group and between-group comparisons using two-way repeated-measures analysis of variance. The effect size will be calculated using partial eta-squared (η_p^2). The interpretation of η_p^2 will be a small effect size for a value of 0.01, a moderate effect size for a value of 0.06 and a large effect size for a value of 0.14. The minimum detectable change will be calculated based on

the SE of measurement.²¹ For each test, the significance level will be set at $p < 0.05$, with a 95% CI.²²

DISCUSSION

Exercise training has positive benefits for physical function in older adults.²³ A multicomponent exercise plan is recommended by expert consensus guidelines.²⁴ Because of the complementary and diverse benefits of performing different types of exercise training, multicomponent exercise may have more powerful positive effects on physical function. Resistance and balance training should be emphasised.²⁵

The contribution of age-related muscle mass loss to functional decline is mainly mediated by a decrease in muscle strength.^{26–28} As humans age, muscle strength declines at a rate 2–5 times faster than muscle size.²⁹ There is substantial evidence that muscle weakness is associated with a range of negative age-related health outcomes, including diabetes,³⁰ disability,^{31–32} cognitive decline,^{33–36} osteoporosis³⁷ and early all-cause mortality.^{14–38–40} RT has been shown to be a viable and effective way to combat muscle weakness and physical frailty.⁴¹ There is also strong evidence that RT reduces the effects of ageing on neuromuscular function and functional capacity.^{42–47} All forms of RT have the potential to improve muscle strength, mass and power output.^{48–49} Because physical function is related to muscle strength and power,^{50–52} interventions to maintain and build strength and power in older adults are necessary to maintain physical function. Resistance exercise yields the most consistent gains in functional tasks and increased health-related quality of life.⁵³ RT can specifically attenuate age-related changes in functional mobility, including those that improve gait speed, static and dynamic balance, and reduce the risk of falls.⁵⁴ Thus, RT may improve flexibility, physical function and performance of daily living activities to help older adults maintain independence.

Age-related declines in physical function are only partially explained by a loss of muscle mass or muscle strength. Other fundamental aspects of motor control also strongly influence the functional performance of activities of daily living in older adults, including deterioration in dynamic balance and motor coordination. Studies have shown that long-term adherence to RBT integrated into daily life is beneficial in delaying the decline of physical function in older adults.⁵⁵ A review of the literature⁵⁶ found that RBT has better effects on lower limb muscle strength and balance and other functions among older adults with different health statuses. Therefore, TUG, which assesses dynamic balance, walking speed (UWS and MWS), 30s CST, which assesses lower extremity muscle function, and 30s ACT, which assesses upper extremity muscle strength, have been selected as the primary outcome indicators for this trial. In addition, the 2 min ST to assess cardiopulmonary function and BST and CSRT to assess flexibility will be used as secondary outcome indicators in this study. Determining the multidimensional

effects of long-term RBT on physical function in older adults will deepen our understanding of physical function decline and provide an evidence-based foundation for optimising exercise intervention programmes. We will screen participants for normal cognitive function by using the MoCA to reduce the potential for an effect of cognitive function on physical function in older adults.

We acknowledge that this proposed trial has some limitations. RT based on the vertical vibration platform equipment, that is, RBT, is suitable for most older people, except for people with uncontrolled hypertension, a prosthesis, a pacemaker or severe diabetes complications. Despite the overall length of the exercise intervention having the potential to lead to high study attrition, the use of the OMNI-RES to monitor the intensity of the exercise intervention is tolerable and enjoyable for older adults, which are important factors in determining their continued participation in the study.⁵⁷ Moreover, to attempt to mitigate this limitation, when selecting participants for the formal experiment, we plan to include a survey to determine the amount of time each individual has resided in their current community; for inclusion in the study, individuals will need to have resided in the community for at least 6 months. Although scientific testing or questioning of the control group is planned to ensure that participants do not start a regular exercise programme during the 24 weeks, the control group will not interact with the healthcare workers who will provide medical supervision to the exercise intervention groups, which may bias the results.

ETHICS AND DISSEMINATION

Prior to conducting the experiment, all participants will sign an informed consent form. This proposal was reviewed and approved by the Shanghai University of Sport Research Ethics Committee. The results will be disseminated to the trial participants and as a peer-reviewed publication.

Contributors GJ designed the study, collected and analysed the data and wrote the manuscript. XW oversaw all analyses and interpretation of the data and preparation of the manuscript. All authors contributed to and approved the final version.

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Competing interests None declared.

Patient and public involvement Patients and/or the public were involved in the design, or conduct, or reporting, or dissemination plans of this research. Refer to the Methods section for further details.

Patient consent for publication Not applicable.

Provenance and peer review Not commissioned; externally peer reviewed.

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