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Comparison of open- and closed-chain exercises in improving the inhibitory control ability of the elderly: a protocol for a randomized controlled clinical trial

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Article Type: Clinical Study Protocol

Keywords: Elder; Open-chain exercise; Closed-chain exercise; Inhibitory control ability; Study protocol

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Abstract

Introduction As people age, they are more likely to experience a decline in their response inhibition ability, which interferes with daily life. Previous studies have shown that exercise intervention can improve the cognitive ability of the elderly, but research on open- and closed-chain exercises to improve the response inhibition in this age group is still limited. This study will explore the advantages of long-term intervention of table tennis (open-chain exercise) compared with fit aerobics (closed-chain exercise) on the inhibitory control ability of the elderly.

Methods and analysis A single-blind randomized controlled trial will be conducted. A total of 90 elderly subjects will be recruited and allocated randomly to the following groups: table tennis, fit aerobics, and control. The interventions for the table tennis group and the fit aerobics group will be implemented in three 60-min sessions

per week for 6 months; the control group will receive no exercise intervention. The primary assessment will be behavioral indicators of inhibitory control ability in the elderly based on the stop signal task (SST). The secondary outcomes will include cognitive ability, mental status, and depression in the elderly. Assessments will be conducted at baseline, 3 months, 6 months, and 12 months.

Ethics and dissemination This study was approved by the Shanghai University of Sport Research Ethics Committee (102772019RT012) and will provide reference for the advantages of table tennis compared with other types of sports in improving the inhibitory control ability of the elderly. The results of this study will provide a theoretical basis for choosing the best exercise program to improve the inhibitory control ability of the elderly.

Trial registration number This study has been registered prospectively in the Chinese Clinical Trial Registry (ChiCTR2100043616, 23 February 2021).

Cover letter

Editor-in-Chief

BMJ Open

April 3, 2021

Dear editor,

We would like to submit our manuscript entitled **" Comparison of open- and closed-chain exercises in improving the inhibitory control ability of the elderly: a protocol for a randomized controlled clinical trial"** for publication as a *protocol* in BMJ Open.

This study will be conducted in a single-blind randomized controlled trial, a six-month open- and closed-chain exercises intervention will be used to study the effects of long-term on the inhibitory control ability in elderly. The study is scheduled to begin in August 2021. This study will use the stop signal task (SST) to explore how different types of exercise experience affect the response inhibition ability in the elderly. We will also explore whether sports involving open-chain exercises can improve the cognitive level, depression state, and mental state of the elderly while improving their inhibition and control ability.

Through multi-dimensional measurements of the participants, we hope to provide a more sufficient theoretical basis for the mechanism of improving the inhibition and control ability of the elderly through exercise.

We confirm that this manuscript has not been published elsewhere and is not under consideration by another journal. All authors have approved the manuscript and agree with submission to BMJ Open. The study was supported by a grant from the National Natural Science Foundation of China(3197070657) . The authors have no conflicts of interest to declare.

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We look forward to hearing from you at your earliest convenience.

Yours sincerely,

Jia-Ning Wei, Comparison of open- and closed-chain exercises in improving the inhibitory control ability of the elderly: a protocol for a randomized controlled clinical trial

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Type of Manuscript: Clinical Study Protocol

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Abbreviations

SST, Stop signal task

SSRT, stop signal response time

SSD, stop signal delay

MoCA, Montreal Cognitive Assessment

BDI-II, Beck Depression Inventory (2nd edition);

MMSE, Mini Mental State Examination

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Abstract

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Trial registration number This study has been registered prospectively in the Chinese Clinical Trial Registry (ChiCTR2100043616, 23 February 2021).

Strengths and limitations of this study

1. The results of this study will provide a choosing the best exercise program to improve the inhibitory control ability of the elderly.
2. The patients will come from one geographic area which limits the generalisability.

Introduction

Response inhibition ability is a type of cognitive control ability that can achieve behavioral goals by adjusting perception and motor function in the changing environment as well as be used to solve conflicts. As people age, they are likely to experience a decline in their response inhibition ability,[1-4] which can interfere with daily life and even the ability to live independently. Although some studies have shown that exercise intervention can improve the cognitive ability of the elderly, there are few studies on the effect of exercise intervention on reactive inhibition ability. In particular, research on the different types of exercise to improve the response inhibition ability of the elderly is still limited.

Sports can be divided into closed kinetic chain activities and open kinetic chain activities.[5] The operating environment of closed-chain exercises, such as fit aerobics, fitness running, etc., is stable; and the operating state is determined by the operator. In contrast, the operating environment of open-chain exercises, including those involved in the sports of table tennis, basketball, etc., is unstable; and the operation state is determined by external conditions, such as a ball and opponents. In open-chain exercises, the participant must continuously adjust their behavior to unpredictable stimuli and must invest more cognitive resources in the decision-making process. It has been demonstrated that intervention with long-term open-chain exercise can improve cognitive function better than closed-chain exercise, but whether it can improve inhibitory control ability better is not clear.

As one of the classical paradigms to test response inhibition, the stop signal task (SST) tests the complete suppression of an ongoing action. The SST instructs the participant to perform a response when the go signal appears, but after a few go signals appear, a stop signal will appear at a specific time interval, and the individual will be asked to stop the response as far as possible.[6] The strengths of this test are that a stop signal to evoke controlling behavior is administered after a go signal is used, and the interval between these two signals dynamically changes regularly.[7] In addition, the SST is capable of quantizing inhibitory control behavior. However, no response occurs when the participant holds up successfully. The stop signal response time (SSRT) is a more sensitive indicator to evaluate the inhibitory control ability.[8] In short, to calculate the SSRT, all go-reactions (i.e., go-trials in which the response

was missed) are rank-ordered and assigned the maximum response time in order to compensate for the lacking response. Afterwards, the most recent stop signal delay (SSD) is subtracted from the response time corresponding to the stop-signal response percentile. The resulting value is termed the SSRT.[9,10] These results can be used as an important index to evaluate the inhibitory control ability.

The proposed randomized clinical trial will examine the effects of table tennis (open-chain exercise) and fit aerobics (closed-chain exercise) on the primary outcome (behavioral task) of inhibitory control ability as well as on the secondary outcomes of cognitive ability, mental status, and depression in the elderly. We hypothesized that different types of exercise intervention can affect the inhibitory control ability to varying degrees and that the effect of open-chain exercises is better.

Methods

Study design

This study protocol of a pilot study is designed as a prospective, single-blind randomized controlled trial. Eligible participants will be randomized into table tennis, fit aerobics, or control groups at a 1:1:1 ratio. The duration of exercise intervention will be 6 months. The cognitive function test (questionnaire and behavioral task) will be conducted before the intervention as well as at 3 months, 6 months, and 12 months after the intervention. Participants who meet the criteria will undergo baseline assessments. All evaluations will be done at baseline and immediately after the exercise intervention (See Figure 1). We will recruit healthy right-handed elderly

participants with normal or corrected-to-normal vision and without a history of neurological diseases in the same way.

Ethics and dissemination

All participants who meet the inclusion and exclusion criteria will be required to sign an informed consent form prior to enrolling in the study. This study was approved by the Shanghai University of Sport Research Ethics Committee (102772019RT012).

Figure 1 Flow diagram of the study design

Participants

Any participants with chronic cardiovascular or neurological diseases will be excluded. In addition, those with a regular exercise routine will be excluded. All participants will be between the ages of 60 and 70 years old and right-handed as assessed by the Edinburgh Handedness Inventory. Moreover, they must have normal or corrected-to-normal vision and no signs of depression or cognitive impairment as detected by the Beck Depression Inventory, 2nd edition (BDI-II) and the Mini Mental State Examination (MMSE).

Before and after the intervention, all groups will have their demographics statistically analyzed for factors such as health status, physical fitness, and cognitive function (Table 1). Intergroup differences will be minimized before the intervention.

Table 1 Demographic and clinical characteristics of the study participants

	Open group	Closed group	Control
Age			
Gender (male:female)			
Hight			
Body mass index (kg/m^2)			
HRmax			
Score for self-reported habitual physical activity			
MoCA			
BDI-II			
MMSE			
Behavioral tests for cognitive ability (RT)			
Behavioral test about cognitive ability (ACC)			

MoCA, Montreal Cognitive Assessment; BDI-II, Beck Depression Inventory (2nd edition); MMSE, Mini Mental State Examination; Behavioral tests for cognitive ability: Stroop task testing, n-back task testing, task-switch task testing; RT, response time; ACC, accuracy.

Sample size

From our previous studies on the modulation of SST performance,[11,12] we expected an effect of r = 0.4. Together with an α-value of 0.05 and a power of 1 – β = 0.9, a sample of at least 72 participants (24/group) was planned to find a similar effect. Calculations were carried out using G*Power, version 3.1,[13] with anticipation of a 20% attrition rate. Therefore, we plan to recruit 90 subjects (30/group).

Evaluation Procedures

Exercise intervention

The exercise intervention will last for 6 months. The participants will be divided into three groups: table tennis, fit aerobics, and control. The table tennis (open-chain) and fit aerobics (closed-chain) groups will train for 60 min, three times a week. The exercise intensity will be monitored, ensuring that the heart rate remains in the range of 60–70% of the maximum heart rate (HRMAX = 220 – age). During the training period, the exercise intensity will be monitored by the experimenter through real-time heart rate monitoring and the subject's subjective reaction. The exercise load and heart rate responses of the subjects will be recorded at each training session and adjusted accordingly with an increase of aerobic capacity. The entire intervention process will be monitored in real time by health care professionals.

Table tennis group

Each session will consist of a warm-up for 10 min, table tennis practice under the guidance of a coach for 40 min, and relaxation for 10 min. The degree of difficulty of training throughout the program will be gradually increased. The training will consist of the following seven main parts: (1) footwork; (2) the serve; (3) forehand backhand attack; (4) forehand backhand loop; (5) kill shot; (6) continuous hitting of directional

or nondirectional balls randomly sent by the server; and (7) comprehensive practice. All the technical movements will be from simple to complex.

Fit aerobics group

The participants in the closed-chain exercise group will attend a supervised fit aerobics class of the same frequency, duration, and length as the open-chain exercise group. Fit aerobics at 50–60% of the heart rate reserve for the first two weeks, followed by 70–75% of the heart rate reserve. Each fit aerobics class will consist of warm-up activities for 10 min, basic aerobics activities for 30 min, strength exercises or mat exercises for 10 min, and relaxation and stretching for 10 min. The fit aerobics training will involve the following: 1) jogging, rope skipping, and/or gymnastics to warm up and achieve a slightly sweating body, and the heart rate will be slightly faster; 2) stepping, side parallel step, side cross step, jumping jacks, lunging, kicking, and so on. Following the rhythm of the music, each action will be reduced from four sets to two sets and then to one set; 3) upper body exercises, lower body exercises, core strength exercises, or yoga exercises related to them; 4) relax the shoulder, elbow, hip, and knee joints by doing a few stretches to help relax the muscles.

Control group

For the control group, health testing, cognitive ability testing, and telephone or personal interviews will be carried out in addition to regular physical and mental health education lectures.

SST protocol

The SST was programmed using E-prime 2, in which the subjects will be asked to press a "←" button or a "→" button according to the left and right arrow directions. In 25% of the trials, the arrow will turn red and a gray triangle will appear; the participants will press the button to stop or give no response. The interval of stimulation will be dynamically adjusted according to the tracking procedure. The task will be divided into four groups of 120 trials each. The task flow is shown in Figure 2. The execution go signal reaction time (GoRT), stop response reaction time (SRRT), SSD, and SSRT will be investigated.

Figure 2 Stop signal task flow chart

The instructions for the experiment will be follows: Welcome to the experiment. First, "+" will appear in the center of the screen to alert the user to begin the keystroke reaction, and the right index finger should be placed on the "↓" to prepare for the experiment. When the black arrow appears in the center of the screen, use your right index finger to press the button. When the left arrow appears, use your

index finger to press the "←" key on the keyboard. When the right arrow appears, use your index finger to press the "→" key on the keyboard. After each key response, the right index finger should quickly return to the "↓" key to wait for the next response. When the black arrow in the center of the screen turns red and a small gray triangle appears, please stop the keystroke reaction immediately. When the red arrow appears in the center of the screen, please do not perform any keystroke reaction. Let's move on to practice.

Outcomes

Primary outcome

Behavioral task

The task will include randomly interspersed no-go and stop-signal trials, which will enable us to examine both types of inhibition. A total of 480 trials will be performed, including 75% go trials and 25% stop trials. On go trials, the subjects will respond to a left/right black arrow (1000 ms) by pressing the buttons with their right hand. Responses will be made with the index finger (for the left or right arrow). In the stop-signal trials, a response will be initially cued by a left/right black arrow, but the arrow color will change to red concurrent with a gray triangle after a SSD, and the subjects will be asked not to respond. The SSD will be varied from trial to trial by using a step-up/down algorithm with an initial estimate of 250 ms to maintain 50% successful inhibition. The task flow chart is shown in Figure 3.

Figure 3 Stop behavioral task

The task will consist of randomly interspersed no-go and stop-signal trials. A total of 480 trials will be performed (75% go, 25% stop).

Secondary outcomes

Secondary outcome measures will include the following: (1) Montreal Cognitive Assessment (MoCA); (2) BDI-II; (3) MMSE; (4) Stroop task testing; (5) n-back task testing; and (6) task-switch task testing (Table 2). The process of inhibitory control is the process of inhibition, refresh, and switching of the response task through cognitive function, so we will test the abilities of inhibition, refresh, and switching in the cognitive process of the elderly with different exercise types before and after the intervention by the Stroop task, the n-back task, and the task-switch task to compare their inhibitory control ability. The details of each outcome and instrument will be compiled as in Table 2.

Table 2 The differences among the three groups of subjects at various stages

	Group	Baseline	6 months	12 months	18 months	24 months	F (P value) Time effect	F (P value) Group effect	F (P value) Interaction effect
MoCA	Open								
	Closed								

BDI-II	Control	
	Open	
	Closed	
MMSE	Control	
	Open	
	Closed	
Stroop (RT)	Control	
	Open	
	Closed	
n-back (ACC)	Control	
	Open	
	Closed	
Task-switch (ACC)	Control	
	Open	
	Closed	

MoCA, Montreal Cognitive Assessment; BDI-II, Beck Depression Inventory (2nd edition); MMSE, Mini Mental State Examination; RT, response time; ACC, accuracy.

MoCA

The MoCA is an assessment tool for the rapid screening of cognitive dysfunction. It includes 11 items in 8 cognitive domains: attention and concentration, executive

function, memory, language, abstract thinking, and computation. The highest possible total score is 30, and a score of 26 or more is normal. It has a high sensitivity and a short test time, so it is suitable for clinical application.

BDI-II

The BDI-II contains 21 topics, which are suitable for people older than 13 years old. The areas of focus include symptoms of depression, such as despair, sensitivity, ways of understanding things, and physical characteristics, such as fatigue, weight loss, and decreased sexual ability.

MMSE

The MMSE scale includes the following seven aspects: time orientation, place orientation, immediate memory, attention and calculation, delayed memory, language, and visual space. There are a total of 30 questions asked in the exam, with 1 point awarded for each correct answer, and 0 points given for each wrong answer or unanswered question. The total score range of the scale is 0–30 points. The test scores are closely related to the educational level of the subject. The normal cut-off values are as follows: illiterate subjects, >17; primary school education only, >20; junior high school education and above, >24.

Stroop task

After a period of exercise intervention, comparison of the Stroop task response time

between the open-chain, closed-chain, and control groups will be used to explore which types of exercise can improve cognitive inhibition ability.

N-back task

By comparing the n-back task accuracy of the elderly in the three groups, the improvement of the cognitive refresh ability of each group will be compared under different cognitive loads.

Task-switch task

By comparing the task-switch accuracy of the three groups under different stimulus conditions, we will determine which type of exercise can improve the cognitive transformation ability most significantly.

Patient and public involvement

Participants have not been involved in the study recruitment. The authors conceived the initial research questions and outcome measures, and modified according to the telephone interviews with patients and their guardians by a research assistant. In order to assure the safety and feasibility of the intervention, we invited six elderly peoples to learn and practise the table tennis and fit aerobics exercise before designing the RCT. Table tennis and fit aerobics exercise were revised based on the exercise performance and feedback provided by the participants. The burden of the intervention will be assessed by patients and their advisors through face-to-face

interviews before signing informed consent. The findings of the study will be disseminated to the participants and their guardians.

Statistical analysis

Repeated-measures analysis of variance will be used to determine the effects of different types of exercise (open, closed, or control) on the primary outcomes (GoRT, SRRT, SSD, and SSRT) as well as on the secondary outcomes (MOCA score, BDI-II score, MMSE score, Stroop response time, n-back accuracy, task-switch accuracy), with group and time serving as factors.

Discussion

Previous studies have shown that open-chain exercises require more regulating capacity than closed-chain exercises.[14] First, a study comparing the cognitive control of sports involving open-chain exercises with that of closed-chain exercises has revealed that athletes engaging in open-chain exercises have an advantage in cognitive control.[15] Then some researchers found that athletes participating in open-chain exercises have a faster switching speed, fewer cognitive resources, and a higher efficiency in the inhibition process.[16] At the same time, another study has demonstrated that athletes who engage in open-chain exercises have a stronger reaction switching capability.[17] Based on this evidence, participating in sports involving open-chain exercises can improve the ability of inhibition, refresh, and conversion in the inhibitory control process. Therefore, in this study, the Stroop task,

n-back task, and task-switch task were selected as secondary outcomes to investigate the inhibition, refresh, and transformation abilities, respectively, of the participants. Determining the effect of long-term intervention of different types of sports on the inhibitory control ability of the elderly will improve our understanding of inhibitory control degradation and support the development of diversified training programs.

This study will use the SST to explore how different types of exercise experience affect the response inhibition ability in the elderly. Because of the interactions of the cognitive level, depressive state, and mental state with the inhibitory control ability, we will perform multiple MoCA, BDI-II, MMSE measurements before and after each intervention. We will also explore whether sports involving open-chain exercises can improve the cognitive level, depression state, and mental state of the elderly while improving their inhibition and control ability. Through multi-dimensional measurements of the participants, we hope to provide a more sufficient theoretical basis for the mechanism of improving the inhibition and control ability of the elderly through exercise.

This study will have several limitations. The effect of long-term exercise intervention on cognitive control is greatly influenced by the screening and control of subjects. How to select and control participants in a longitudinal study is one of the difficulties of this project. In this research, the screening principles of the subjects will be determined in the longitudinal study, and the inclusion criteria and exclusion criteria will be strictly defined, especially the experimental groups and the control group in terms of age, physical level, intervention time, and intensity. In addition,

because the exercise that will serve as an intervention will be widely known to the participants, the single-blind design may expose the study to risks of bias stemming from performance and evaluation, which may potentially lead to overestimation of the effects of exercise.

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Contributorship statement

Ke Liu: Conceptualization, Methodology, SoftwarePriya. Lanlan Zhang:Writing-Reviewing and Editing. Jian Zhang: Visualization, Investigation. Jia-Ning Wei: Data curation, Writing- Original draft preparation.

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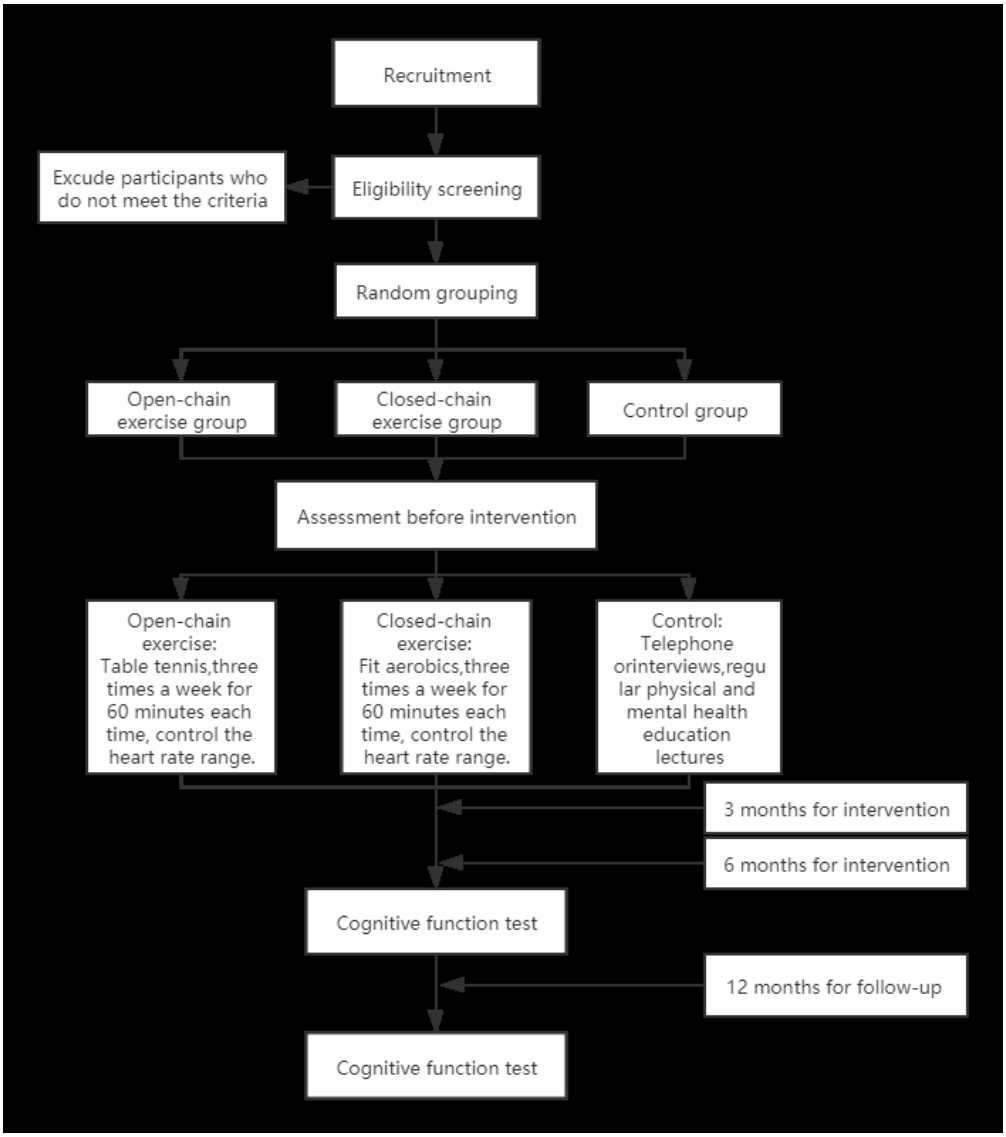

Figure 1. Flow diagram of the study design

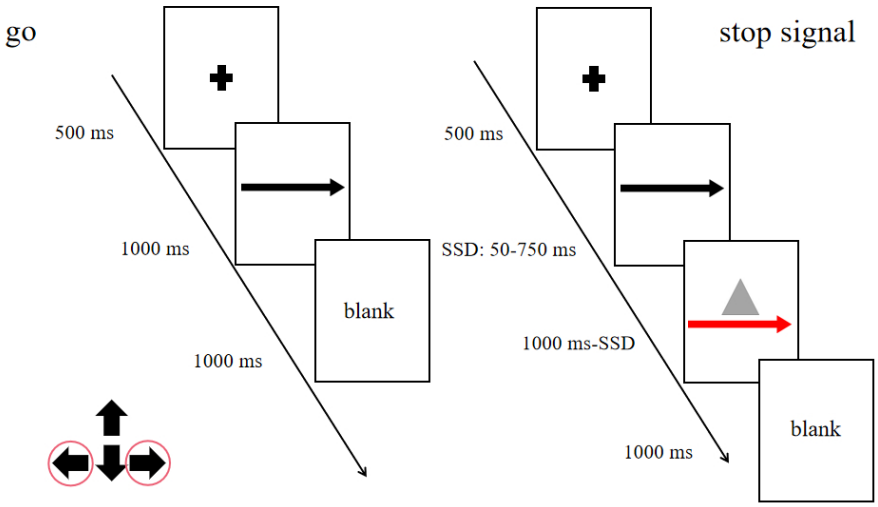

Figure 2. Stop signal task flow chart

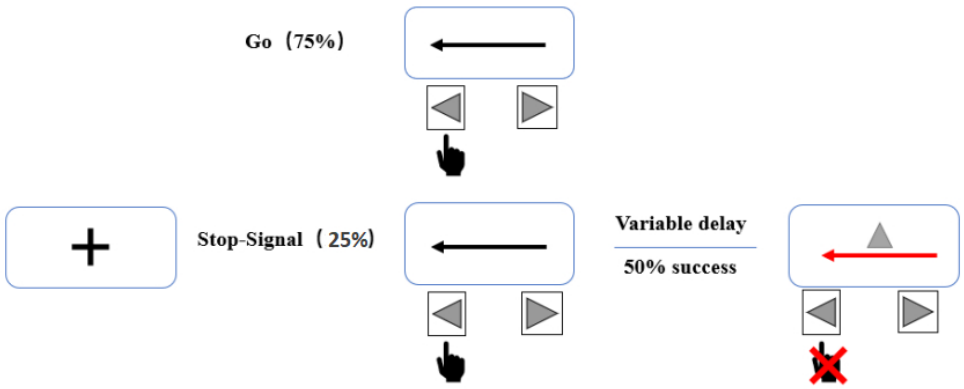

Figure 3. Stop behavioral task
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Title: Comparison of open- and closed-chain exercises in improving the response inhibitory ability of the elderly: a protocol for a randomized controlled clinical trial

Article Type: Clinical Study Protocol

Keywords: Elder; Open-chain exercise; Closed-chain exercise; Response inhibitory ability; Study protocol

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Abstract

Introduction As people age, they are more likely to experience a decline in their response inhibition ability, which interferes with daily life. Previous studies have shown that exercise intervention can improve the cognitive ability of the elderly, but research on open- and closed-chain exercises to improve the response inhibition in this age group is still limited. This study will explore the advantages of long-term intervention of table tennis (open-chain exercise) compared with fit aerobics (closed-chain exercise) on the response inhibitory ability of the elderly.

Methods and analysis A single-blind randomized controlled trial will be conducted. A total of 90 elderly subjects will be recruited and allocated randomly to the following groups: table tennis, fit aerobics, and control. The interventions for the table tennis group and the fit aerobics group will be implemented in three 60-min sessions

per week for 6 months; the control group will receive no exercise intervention. The primary assessment will be behavioral indicators of response inhibitory ability in the elderly based on the stop signal task (SST). The secondary outcomes will include cognitive ability, mental status, and depression in the elderly. Assessments will be conducted at baseline, 3 months, 6 months, and 12 months.

Ethics and dissemination This study was approved by the Shanghai University of Sport Research Ethics Committee (102772019RT012) and will provide reference for the advantages of table tennis compared with other types of sports in improving the response inhibitory ability of the elderly. The results of this study will provide a theoretical basis for choosing the best exercise program to improve the response inhibitory ability of the elderly.

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Abbreviations

SST, Stop signal task

SSRT, stop signal response time

SSD, stop signal delay

MoCA, Montreal Cognitive Assessment

BDI-II, Beck Depression Inventory (2nd edition);

MMSE, Mini Mental State Examination

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Strengths and limitations of this study

1. The results of this study will provide a choosing the best exercise program to improve the response inhibitory ability of the elderly.
2. The effect of long-term exercise intervention on cognitive control is greatly influenced by the screening and control of subjects.
3. How to select and control participants in a longitudinal study is one of the difficulties of this project.
4. The patients will come from one geographic area which limits the generalisability.

Introduction

Response inhibition ability is a type of cognitive control ability that can achieve behavioral goals by adjusting perception and motor function in the changing environment as well as be used to solve conflicts.[1] As people age, they are likely to experience a decline in their response inhibition ability,[2-5] which can interfere with daily life and even the ability to live independently. Although some studies have

shown that exercise intervention can improve the cognitive ability of the elderly,[6] there are few studies on the effect of exercise intervention on reactive inhibition ability. In particular, research on the different types of exercise to improve the response inhibition ability of the elderly is still limited.

Sports can be divided into closed kinetic chain activities and open kinetic chain activities.[7] It is different from Open kinetic chain exercise (OKCE) and closed kinetic chain exercise (CKCE) in exercise prescription.[8] The open and closed mentioned here refer to the movement environment and movement methods, not the fixed point of the extremity during movements. The operating environment of closed-chain exercises, such as fit aerobics, fitness running, etc., is stable; and the operating state is determined by the operator. In contrast, the operating environment of open-chain exercises, including those involved in the sports of table tennis, basketball, etc., is unstable; and the operation state is determined by external conditions, such as a ball and opponents. In open-chain exercises, the participant must continuously adjust their behavior to unpredictable stimuli and must invest more cognitive resources in the decision-making process. Previous studies have shown that open-chain exercises require more regulating capacity than closed-chain exercises.[9] First, a study comparing the cognitive control of sports involving open-chain exercises with that of closed-chain exercises has revealed that athletes engaging in open-chain exercises have an advantage in cognitive control. It has been demonstrated that intervention with long-term open-chain exercise can improve cognitive function

better than closed-chain exercise,[10] but whether it can improve response inhibitory ability better is not clear.

As one of the classical paradigms to test response inhibition, the stop signal task (SST) tests the complete suppression of an ongoing action. The SST instructs the participant to perform a response when the go signal appears, but after a few go signals appear, a stop signal will appear at a specific time interval, and the individual will be asked to stop the response as far as possible.[11] The strengths of this test are that a stop signal to evoke controlling behavior is administered after a go signal is used, and the interval between these two signals dynamically changes regularly.[12] In addition, the SST is capable of quantizing inhibitory control behavior. However, no response occurs when the participant holds up successfully. The stop signal response time (SSRT) is a more sensitive indicator to evaluate the response inhibitory ability.[13] In short, to calculate the SSRT, all go-reactions (i.e., go-trials in which the response was missed) are rank-ordered and assigned the maximum response time in order to compensate for the lacking response. Afterwards, the most recent stop signal delay (SSD) is subtracted from the response time corresponding to the stop-signal response percentile. The resulting value is termed the SSRT.[14,15] These results can be used as an important index to evaluate the response inhibitory ability.

The proposed randomized clinical trial will examine the effects of table tennis (open-chain exercise) and fit aerobics (closed-chain exercise) on the primary outcome (behavioral task) of response inhibitory ability as well as on the secondary outcomes of cognitive ability, mental status, and depression in the elderly. We hypothesized that

different types of exercise intervention can affect the response inhibitory ability to varying degrees and that the effect of open-chain exercises is better.

Methods

Study design

This study protocol of a pilot study is designed as a prospective, single-blind randomized controlled trial. Eligible participants will be randomized into table tennis, fit aerobics, or control groups at a 1:1:1 ratio. The duration of exercise intervention will be 6 months. The cognitive function test (questionnaire and behavioral task) will be conducted before the intervention as well as at 3 months, 6 months, and 12 months after the intervention. Participants who meet the criteria will undergo baseline assessments. All evaluations will be done at baseline and immediately after the exercise intervention (See Figure 1). We will recruit healthy right-handed elderly participants with normal or corrected-to-normal vision and without a history of neurological diseases in the same way.The study is scheduled to begin in August 2021 and continue until August 2023.

Figure 1 Flow diagram of the study design

Participants

Any participants with heart disease, neurological disorder, musculoskeletal disorders, and other conditions not suitable for physical activity, contraindications to fMRI or TMS will be excluded. In addition, those with a regular exercise routine will be

excluded. All participants will be between the ages of 60 and 70 years old and right-handed as assessed by the Edinburgh Handedness Inventory. Moreover, they must have their own residence.

Before and after the intervention, all groups will have their demographics statistically analyzed for factors such as health status, physical fitness, and cognitive function (Table 1). Intergroup differences will be minimized before the intervention.

Table 1 Demographic and clinical characteristics of the study participants

	Open group	Closed group	Control
Age			
Gender (male:female)			
Hight			
Body mass index (kg/m^2)			
HRmax			
Score for self-reported habitual physical activity			
MoCA			
BDI-II			
MMSE			
Behavioral tests for cognitive ability (RT)			
Behavioral test about cognitive ability (ACC)			

MoCA, Montreal Cognitive Assessment; BDI-II, Beck Depression Inventory (2nd edition); MMSE, Mini Mental State Examination; Behavioral tests for cognitive ability: Stroop task testing, n-back task testing, task-switch task

testing; RT, response time; ACC, accuracy.

Sample size

From our previous studies on the modulation of SST performance,[16,17] we expected an effect of r = 0.4. Together with an α-value of 0.05 and a power of 1 – β = 0.9, a sample of at least 72 participants (24/group) was planned to find a similar effect. Calculations were carried out using G*Power, version 3.1,[18] with anticipation of a 20% attrition rate. Therefore, we plan to recruit 90 subjects (30/group).

Randomisation

Eligible participants will be randomized into table tennis, fit aerobics, or control groups at a 1:1:1 ratio after consenting and baseline assessment.I will use The Excel software to code the subjects in 1-90 according to the recruitment time, and then use the formula '=RAND()' to generate the corresponding random sequence. By sorting the random sequence and then grouping it, 90 subjects will be randomly grouped.

Exercise intervention

The exercise intervention will last for 6 months. The participants will be divided into three groups: table tennis, fit aerobics, and control. The table tennis (open-chain) and fit aerobics (closed-chain) groups will train for 60 min, three times a week. The exercise intensity will be monitored, ensuring that the heart rate remains in the range of 60–70% of the maximum heart rate (HRMAX = 220 – age). During the training

period, the exercise intensity will be monitored by the experimenter through real-time heart rate monitoring and the subject's subjective reaction. The exercise load and heart rate responses of the subjects will be recorded at each training session and adjusted accordingly with an increase of aerobic capacity. The entire intervention process will be monitored in real time by health care professionals.Specific intervention methods are shown in Table 2.

Table 2 Exercise intervention TIDieR

Item NO	Brief name	Group		
		Table tennis group	Fit aerobics group	Control group
1	Why	Table tennis	Fit aerobics	Control
2	What	Participants will be led by professional table tennis coaches for 6 months of table tennis exercise.	Participants will be led by professional fit aerobics coaches for 6 months of fit aerobics exercise.	Keep the original living habits, do not have regular exercise, regularly attend health lectures and accept telephone follow-up.
3	What (materials)	Participants will do 60 minutes of exercise three times a week. Specific exercises will be described later.		Participants will attend biweekly health talks and will be interviewed by phone once a month.
4	What (procedures)	Each participant received a test report before and at 3, 6, and 12 months after the start of the exercise so that they could understand their physical and psychological changes.		
5	Who provided	Table tennis coaches is the second level table tennis athlete in China from Shanghai University of Sport.The psychology-related tests were completed by ph. D. students majoring in psychology at Shanghai University of Sport.	Fit aerobics coaches is the second level fit aerobics athlete in China from Shanghai University of Sport.The psychology-related tests were completed by ph. D. students majoring in psychology at Shanghai University of Sport.	The health lecture was completed by ph. D. students majoring in physical Education and training in Shanghai University of Sport, and the telephone return visit was completed by ph. D. students majoring in psychology.

6	How	The exercise intervention will take place in a stationary gym, where the instructor will direct the whole group face to face.		Health lectures will be conducted face to face in a group format, and telephone return visits will be conducted one by one.
7	Where	Table tennis training is held in China Table Tennis College of Shanghai Sport University.There is a professional table tennis training ground.	Fit aerobic trianing is conducted in the School of Physical Education and Training of Shanghai Sport University. There is a professional aerobics training ground.	The health lecture will be held in the conference room of school of Psychology, Shanghai University of Sport.
8	When and how much	The table tennis (open-chain) and fit aerobics (closed-chain) groups will train for 60 min, three times a week. The exercise intensity will be monitored, ensuring that the heart rate remains in the range of 60–70% of the maximum heart rate (HRMAX = 220 – age). Each session will consist of a warm-up for 10 min, table tennis practice under the guidance of a coach for 40 min, and relaxation for 10 min. The degree of difficulty of training throughout the program will be gradually increased. Table tennis at 50–60% of the maximum heart rate for the first two weeks, followed by 60–70% of the maximum heart rate. The training will consist of the following seven main parts: (1) footwork; (2) the serve; (3) forehand backhand attack; (4) forehand backhand loop; (5) kill shot; (6) continuous hitting of directional or nondirectional balls randomly sent by the server; and (7) comprehensive practice. All the technical movements will be from simple to complex.	The participants in the closed-chain exercise group will attend a supervised fit aerobics class of the same frequency, duration, and length as the open-chain exercise group. Fit aerobics at 50–60% of the maximum heart rate for the first two weeks, followed by 60–70% of the maximum heart rate. Each fit aerobics class will consist of warm-up activities for 10 min, basic aerobics activities for 40 min,, and relaxation and stretching for 10 min. The fit aerobics training will involve the following: 1) jogging, rope skipping, and/or gymnastics to warm up and achieve a slightly sweating body, and the heart rate will be slightly faster; 2) stepping, side parallel step, side cross step, jumping jacks, lunging, kicking, and so on. Following the rhythm of the music, each action will be reduced from four sets to two sets	Fortnightly health lectures of 30-50 minutes will be held. A 10-minute return call once a month.

		and then to one set; 3) relax the shoulder, elbow, hip, and knee joints by doing a few stretches to help relax the muscles.
9	Tailoring:	Exercise interventions were performed at 50-60% of maximum heart rate for the first two weeks, followed by 60-70% of maximum heart rate.In order to ensure the safety of participants, the exercise intensity will be gradually increased, and the first two weeks will be mainly acclimatization.
10	How well (planned)	Feedback will be given to each participant on a regular basis, including their physical and psychological data, as well as their motor skills learning performance. Keep them up to date on their progress and status to keep them engaged.

SST protocol

The SST was programmed using E-prime 2, in which the subjects will be asked to press a "←" button or a "→" button according to the left and right arrow directions. In 25% of the trials, the arrow will turn red and a gray triangle will appear; the participants will press the button to stop or give no response. The interval of stimulation will be dynamically adjusted according to the tracking procedure. The task will be divided into four groups of 120 trials each. The task flow is shown in Figure 2. The execution go signal reaction time (GoRT), stop response reaction time (SRRT), SSD, and SSRT will be investigated. GoRT is how long it takes for the participant to respond after the GO (black arrow) appears.SRRT is the time to respond to the stop signal (arrow turning red) task.SSD is the time between the task stimulus and the stop signal.

Figure 2 Stop signal task flow chart

The instructions for the experiment will be follows: Welcome to the experiment. First, "+" will appear in the center of the screen to alert the user to begin the keystroke reaction, and the right index finger should be placed on the "↓" to prepare for the experiment. When the black arrow appears in the center of the screen, use your right index finger to press the button. When the left arrow appears, use your index finger to press the "←" key on the keyboard. When the right arrow appears, use your index finger to press the "→" key on the keyboard. After each key response, the right index finger should quickly return to the "↓" key to wait for the next response. When the black arrow in the center of the screen turns red and a small gray triangle appears, please stop the keystroke reaction immediately. When the red arrow appears in the center of the screen, please do not perform any keystroke reaction. Let's move on to practice.

Outcomes

Primary outcome

Behavioral task

The task will include randomly interspersed no-go and stop-signal trials, which will enable us to examine both types of inhibition. A total of 480 trials will be performed, including 75% go trials and 25% stop trials. On go trials, the subjects will respond to a left/right black arrow (1000 ms) by pressing the buttons with their right hand.

Responses will be made with the index finger (for the left or right arrow). In the stop-signal trials, a response will be initially cued by a left/right black arrow, but the arrow color will change to red concurrent with a gray triangle after a SSD, and the subjects will be asked not to respond. The SSD will be varied from trial to trial by using a step-up/down algorithm with an initial estimate of 250 ms to maintain 50% successful inhibition. The task flow chart is shown in Figure 3.

Figure 3 Stop behavioral task

The task will consist of randomly interspersed no-go and stop-signal trials. A total of 480 trials will be performed (75% go, 25% stop).

Secondary outcomes

Secondary outcome measures will include the following: (1) Montreal Cognitive Assessment (MoCA); (2) BDI-II; (3) MMSE; (4) Stroop task testing; (5) n-back task testing; and (6) task-switch task testing (Table 3). The process of inhibitory control is the process of inhibition, refresh, and switching of the response task through cognitive function, so we will test the abilities of inhibition, refresh, and switching in the cognitive process of the elderly with different exercise types before and after the intervention by the Stroop task, the n-back task, and the task-switch task to compare their response inhibitory ability. The details of each outcome and instrument will be compiled as in Table 3.

Table 3 The differences among the three groups of subjects at various stages

	Group	Baseline	6 months	12 months	18 months	24 months	F (P value) Time effect	F (P value) Group effect	F (P value) Interaction effect
MoCA	Open								
	Closed								
	Control								
BDI-II	Open								
	Closed								
	Control								
MMSE	Open								
	Closed								
	Control								
Stroop (RT)	Open								
	Closed								
	Control								
n-back (ACC)	Open								
	Closed								
	Control								
Task-switch	Open								
	Closed								

(ACC)	Control

MoCA, Montreal Cognitive Assessment; BDI-II, Beck Depression Inventory (2nd edition); MMSE, Mini Mental State Examination; RT, response time; ACC, accuracy.

MoCA

The MoCA is an assessment tool for the rapid screening of cognitive dysfunction. It includes 11 items in 8 cognitive domains: attention and concentration, executive function, memory, language, abstract thinking, and computation.[19] The highest possible total score is 30, and a score of 26 or more is normal. It has a high sensitivity and a short test time, so it is suitable for clinical application.

BDI-II

The BDI-II contains 21 topics, which are suitable for people older than 13 years old. The areas of focus include symptoms of depression, such as despair, sensitivity, ways of understanding things, and physical characteristics, such as fatigue, weight loss, and decreased sexual ability.[20]

MMSE

The MMSE scale includes the following seven aspects: time orientation, place orientation, immediate memory, attention and calculation, delayed memory, language, and visual space.[21] There are a total of 30 questions asked in the exam, with 1 point awarded for each correct answer, and 0 points given for each wrong answer or

unanswered question. The total score range of the scale is 0–30 points. The test scores are closely related to the educational level of the subject. The normal cut-off values are as follows: illiterate subjects, >17; primary school education only, >20; junior high school education and above, >24.

Stroop task

After a period of exercise intervention, comparison of the Stroop task response time between the open-chain, closed-chain, and control groups will be used to explore which types of exercise can improve cognitive inhibition ability[22].

N-back task

By comparing the n-back task accuracy of the elderly in the three groups, the improvement of the cognitive refresh ability of each group will be compared under different cognitive loads.[23]

Task-switch task

By comparing the task-switch accuracy of the three groups under different stimulus conditions, we will determine which type of exercise can improve the cognitive transformation ability most significantly.[24]

Patient and public involvement

Participants have not been involved in the study recruitment. The authors conceived

the initial research questions and outcome measures, and modified according to the telephone interviews with patients and their guardians by a research assistant. In order to assure the safety and feasibility of the intervention, we invited six elderly peoples to learn and practise the table tennis and fit aerobics exercise before designing the RCT. Table tennis and fit aerobics exercise were revised based on the exercise performance and feedback provided by the participants. The burden of the intervention will be assessed by patients and their advisors through face-to-face interviews before signing informed consent. The findings of the study will be disseminated to the participants and their guardians.

Statistical analysis

In order to ensure no inter-group differences in all test indicators after random grouping, Independent-sample T test will be performed on each pretest data after random grouping. Repeated-measures analysis of variance will be used to determine the effects of different types of exercise (open, closed, or control) on the primary outcomes (GoRT, SRRT, SSD, and SSRT) as well as on the secondary outcomes (MOCA score, BDI-II score, MMSE score, Stroop response time, n-back accuracy, task-switch accuracy), with group and time serving as factors.The above data is analyzed by specialized PhD students, they analyse the data be blind to group allocation.

Discussion

Studies have found that elderly people who participate in ball and racket projects have higher health and physical awareness.[25] Pilates exercises decreased depression and improved the balance related to falling in elderly,[26] and also experienced significant improvement in physical, social spiritual, and emotional wellness.[27] Korean scholars found the cognitive/exercise dual-task program was an effective intervention for improving cognitive function, health status, and life satisfaction, and for decreasing depression of the elderly living in the community.[28]

Then some researchers found that athletes participating in open-chain exercises have a faster switching speed, fewer cognitive resources, and a higher efficiency in the inhibition process.[29] At the same time, another study has demonstrated that athletes who engage in open-chain exercises have a stronger reaction switching capability.[30] Based on previous research, participating in sports involving open-chain exercises can improve the ability of inhibition, refresh, and conversion in the inhibitory control process. In the Stoop task, when two different dimensions of a stimulus interfere with each other, it is necessary for participants to inhibit the interfering stimulus, it looked at the participants' ability to suppress interference. In the n-back task, participants' attention capacity and memory capacity could be examined during the process of stimulus updating. In task-switch task, participants need to keep their attention focused when switching between different tasks, so it can investigate the transformation ability of participants in the cognitive process. Therefore, in this study, the Stroop task, n-back task, and task-switch task were selected as secondary outcomes to investigate the inhibition, refresh, and

transformation abilities, respectively, of the participants. Determining the effect of long-term intervention of different types of sports on the response inhibitory ability of the elderly will improve our understanding of inhibitory control degradation and support the development of diversified training programs.

This study will use the SST to explore how different types of exercise experience affect the response inhibition ability in the elderly. Because of the interactions of the cognitive level, depressive state, and mental state with the response inhibitory ability, we will perform multiple MoCA, BDI-II, MMSE measurements before and after each intervention. We will also explore whether sports involving open-chain exercises can improve the cognitive level, depression state, and mental state of the elderly while improving their inhibition and control ability. Through multi-dimensional measurements of the participants, we hope to provide a more sufficient theoretical basis for the mechanism of improving the inhibition and control ability of the elderly through exercise.

This study will have several limitations. In this research, the screening principles of the subjects will be determined in the longitudinal study, and the inclusion criteria and exclusion criteria will be strictly defined, especially the experimental groups and the control group in terms of age, physical level, intervention time, and intensity. In addition, because the exercise that will serve as an intervention will be widely known to the participants, the single-blind design may expose the study to risks of bias stemming from performance and evaluation, which may potentially lead to overestimation of the effects of exercise.

Ethics and dissemination

All participants who meet the inclusion and exclusion criteria will be required to sign an informed consent form prior to enrolling in the study. This study was approved by the Shanghai University of Sport Research Ethics Committee (102772019RT012).

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Contributorship statement

Ke Liu: Conceptualization, Methodology, SoftwarePriya. Lanlan Zhang:Writing-Reviewing and Editing. Jian Zhang: Visualization, Investigation. Jia-Ning Wei: Data curation, Writing- Original draft preparation.

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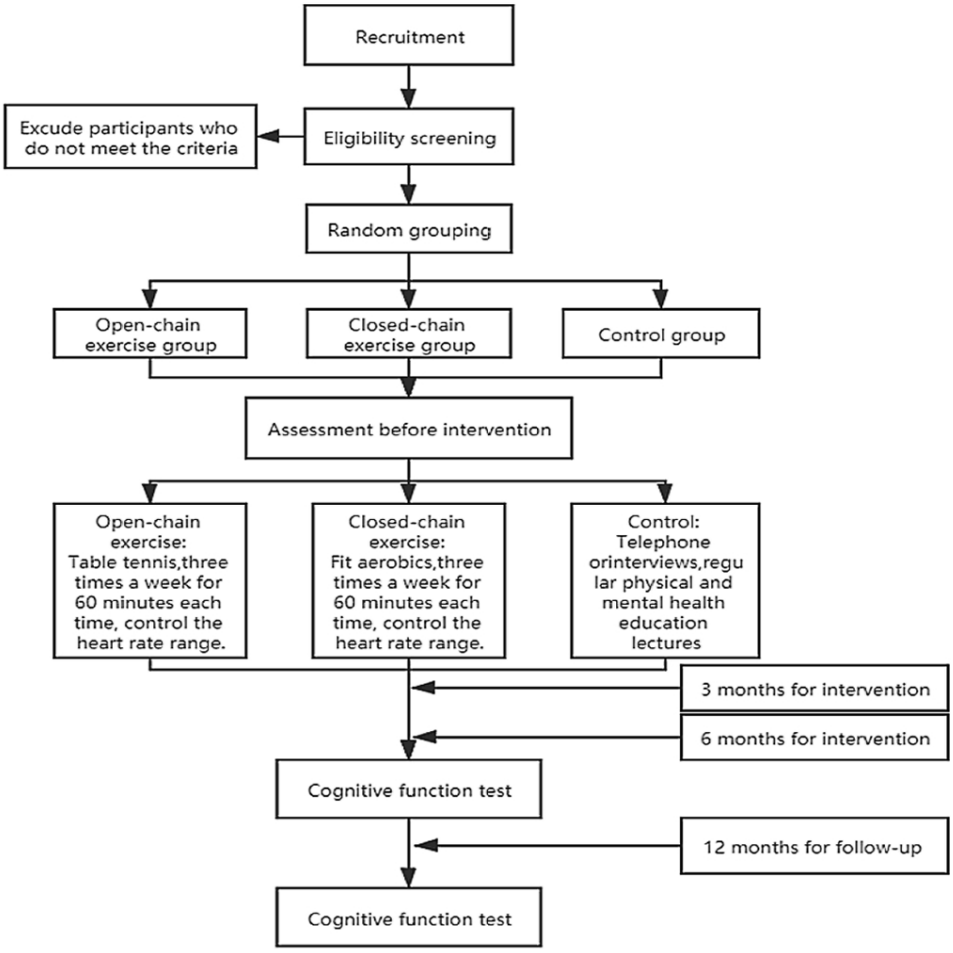

Figure 1 Flow diagram of the study design

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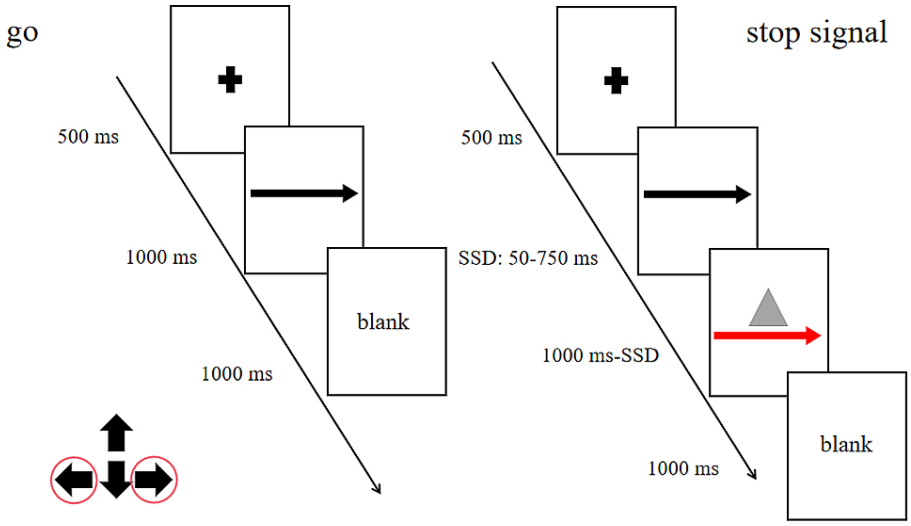

Figure 2. Stop signal task flow chart

90x90mm (300 x 300 DPI)

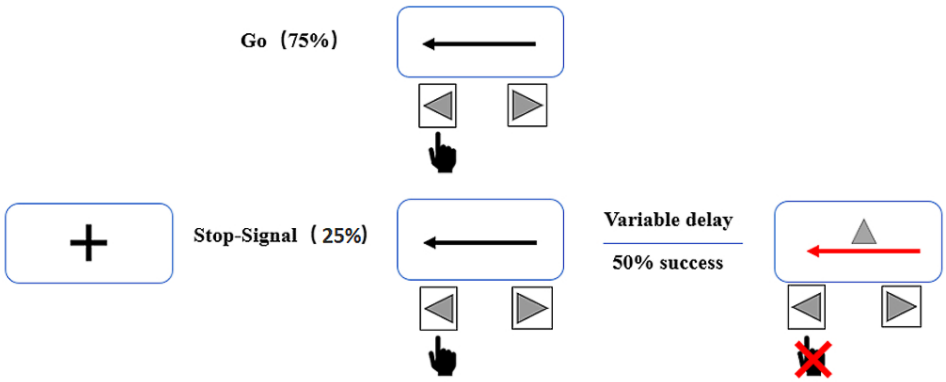

Figure 3. Stop behavioral task
The task will consist of randomly interspersed no-go and stop-signal trials. A total of 480 trials will be performed (75% go, 25% stop).

90x90mm (300 x 300 DPI)

SPIRIT
STANDARD PROTOCOL ITEMS: RECOMMENDATIONS FOR INTERVENTIONAL TRIALS

SPIRIT 2013 Checklist: Recommended items to address in a clinical trial protocol and related documents*

Section/item	Item No	Description
Administrative information		
Title	1	Comparison of open- and closed-chain exercises in improving the response inhibitory ability of the elderly: a protocol for a randomized controlled clinical trial（page 8,line 4）
Trial registration	2a	This study has been registered prospectively in the Chinese Clinical Trial Registry (ChiCTR2100043616, 23 February 2021).（page 9,line 17）
	2b	
Protocol version	3	The study is scheduled to begin in August 2021 and continue until August 2023.（page 12,line 40）
Funding	4	This study was supported by grants from the National Natural Science Foundation of China (3197070657) .（page 26,line 22）
Roles and responsibilities	5a	Ke Liu; Shanghai Punan Hospital of Pudong New District, Shanghai, China; Conceptualization, Methodology, SoftwarePriya. （page 26,line 30）
	5b	
	5c	
	5d	Lan-Lan Zhang: Writing- Reviewing and Editing. Jian Zhang: Visualization, Investigation. Jia-Ning Wei: Data curation, Writing-Original draft preparation.（page 26,line 30）
Introduction		
Background and rationale	6a	As people age, they are more likely to experience a decline in their response inhibition ability, which interferes with daily life. Previous studies have shown that exercise intervention can improve the cognitive ability of the elderly, but research on open- and closed-chain exercises to improve the response inhibition in this age group is still limited. This study will explore the advantages of long-term intervention of table tennis (open-chain exercise) compared with fit aerobics (closed-chain exercise) on the response inhibitory ability of the elderly.（page 8,line 17）

	6b	The elderly who choose not to exercise as the control group can compare the effects of exercise intervention with the intervention group.（page 15,line 21）
Objectives	7	We hypothesized that different types of exercise intervention can affect the response inhibitory ability to varying degrees and that the effect of open-chain exercises is better.（page 11,line 58）
Trial design	8	This study protocol of a pilot study is designed as a prospective, single-blind randomized controlled trial. Eligible participants will be randomized into table tennis, fit aerobics, or control groups at a 1:1:1 ratio. The duration of exercise intervention will be 6 months. The cognitive function test (questionnaire and behavioral task) will be conducted before the intervention as well as at 3 months, 6 months, and 12 months after the intervention. Participants who meet the criteria will undergo baseline assessments. All evaluations will be done at baseline and immediately after the exercise intervention.（page 12,line 17）
Methods: Participants, interventions, and outcomes		
Study setting	9	School of Psychology, Shanghai University of Sport, Shanghai, China（page 15,line 21）
Eligibility criteria	10	Any participants with heart disease, neurological disorder, musculoskeletal disorders, and other conditions not suitable for physical activity, contraindications to fMRI or TMS will be excluded. In addition, those with a regular exercise routine will be excluded. All participants will be between the ages of 60 and 70 years old and right-handed as assessed by the Edinburgh Handedness Inventory. Moreover, they must have their own residence.（page 12,line 53）
Interventions	11a	Table 2 Exercise intervention TIDieR（page 15,line 20）
	11b	Table 2 Exercise intervention TIDieR（page 15,line 20）
	11c	Table 2 Exercise intervention TIDieR（page 15,line 20）
	11d	Table 2 Exercise intervention TIDieR（page 15,line 20）

Outcomes	12	Primary outcome： Behavioral task（RT,ACC）Secondary outcome measures will include the following: (1) Montreal Cognitive Assessment (MoCA); (2) BDI-II; (3) MMSE; (4) Stroop task testing; (5) n-back task testing; and (6) task-switch task testing (Table 3). The process of inhibitory control is the process of inhibition, refresh, and switching of the response task through cognitive function, so we will test the abilities of inhibition, refresh, and switching in the cognitive process of the elderly with different exercise types before and after the intervention by the Stroop task, the n-back task, and the task-switch task to compare their response inhibitory ability. The details of each outcome and instrument will be compiled as in Table 3. （page 19,line 45）
Participant timeline	13	This study protocol of a pilot study is designed as a prospective, single-blind randomized controlled trial. Eligible participants will be randomized into table tennis, fit aerobics, or control groups at a 1:1:1 ratio. The duration of exercise intervention will be 6 months. The cognitive function test (questionnaire and behavioral task) will be conducted before the intervention as well as at 3 months, 6 months, and 12 months after the intervention. Participants who meet the criteria will undergo baseline assessments. All evaluations will be done at baseline and immediately after the exercise intervention (See Figure 1).（page 12,line 17）
Sample size	14	From our previous studies on the modulation of SST performance,we expected an effect of r = 0.4. Together with an α-value of 0.05 and a power of $1-\beta = 0.9$, a sample of at least 72 participants (24/group) was planned to find a similar effect. Calculations were carried out using G*Power, version 3.1, with anticipation of a 20% attrition rate. Therefore, we plan to recruit 90 subjects (30/group).（page 14,line 13）
Recruitment	15	All participants were recruited and counted through the School of Psychology, Shanghai Sport University, and intervened in Shanghai Sport University.（page 15,line 20）

Methods: Assignment of interventions (for controlled trials)

Allocation:

Sequence generation	16a	Eligible participants will be randomized into table tennis, fit aerobics, or control groups at a 1:1:1 ratio after consenting and baseline assessment.I will use The Excel software to code the subjects in 1-90 according to the recruitment time, and then use the formula '=RAND()' to generate the corresponding random sequence. By sorting the random sequence and then grouping it, 90 subjects will be randomly grouped.（page 14,line 29）

Allocation concealment mechanism	16b	Eligible participants will be randomized into table tennis, fit aerobics, or control groups at a 1:1:1 ratio after consenting and baseline assessment.I will use The Excel software to code the subjects in 1-90 according to the recruitment time, and then use the formula '=RAND()' to generate the corresponding random sequence. By sorting the random sequence and then grouping it, 90 subjects will be randomly grouped.（page 14,line 29）
Implementation	16c	Ke Liu will generate the allocation sequence, Jian Zhang will enrol participants, and Jian Zhang will assign participants to interventions.
Blinding (masking)	17a	The data is analyzed by specialized PhD students, they analyse the data be blind to group allocation.（page 23,line 48）
	17b	After the results are processed, the grouping can be announced.
Methods: Data collection, management, and analysis		
Data collection methods	18a	In order to ensure no inter-group differences in all test indicators after random grouping, Independent-sample T test will be performed on each pretest data after random grouping. Repeated-measures analysis of variance will be used to determine the effects of different types of exercise (open, closed, or control) on the primary outcomes (GoRT, SRRT, SSD, and SSRT) as well as on the secondary outcomes (MOCA score, BDI-II score, MMSE score, Stroop response time, n-back accuracy, task-switch accuracy), with group and time serving as factors.（page 23,line 32）
	18b	Feedback will be given to each participant on a regular basis, including their physical and psychological data, as well as their motor skills learning performance. Keep them up to date on their progress and status to keep them engaged.（page 17,line 17）
Data management	19	The data is analyzed by specialized PhD students.（page 23,line 48）
Statistical methods	20a	Repeated-measures analysis of variance will be used to determine the effects of different types of exercise (open, closed, or control) on the primary outcomes (GoRT, SRRT, SSD, and SSRT) as well as on the secondary outcomes (MOCA score, BDI-II score, MMSE score, Stroop response time, n-back accuracy, task-switch accuracy), with group and time serving as factors.（page 23,line 38）
	20b	No
	20c	The data is analyzed by specialized PhD students, they analyse the data be blind to group allocation.（page 23,line 48）
Methods: Monitoring		
Data monitoring	21a	The data is analyzed by specialized PhD students, they analyse the data be blind to group allocation.（page 23,line 48）

	21b	The initiator of the experiment, Professor Zhang will have access to these interim results and make the final decision to terminate the trial
Harms	22	In the Participants gave an informed consent form.
Auditing	23	In the Participants gave an informed consent form.
Ethics and dissemination		
Research ethics approval	24	This study was approved by the Shanghai University of Sport Research Ethics Committee (102772019RT012).（page 8,line 59）
Protocol amendments	25	Upload as attachment.
Consent or assent	26a	PhD students in charge of data collection will collect data within the cognitive function test (questionnaire and behavioral task) will be conducted before the intervention as well as at 3 months, 6 months, and 12 months after the intervention.（page 12,line 24）
	26b	No
Confidentiality	27	Professor Zhang, who is in charge of recruitment, completes the participant information management.
Declaration of interests	28	The authors have no conflicts of interest to declare.
Access to data	29	The result will be made public by the person in charge of the National Natural Science Foundation of China (3197070657)
Ancillary and post-trial care	30	In the Participants gave an informed consent form.
Dissemination policy	31a	This study has been registered prospectively in the Chinese Clinical Trial Registry (ChiCTR2100043616, 23 February 2021).It will be published in accordance with the standards of the Chinese Clinical Trial Registry.
	31b	It will be written in accordance with the standards of the Chinese Clinical Trial Registry.
	31c	It can be viewed in the Chinese Clinical Trial Registry.
Appendices		
Informed consent materials	32	Upload as attachment.
Biological specimens	33	No.

*It is strongly recommended that this checklist be read in conjunction with the SPIRIT 2013 Explanation & Elaboration for important clarification on the items. Amendments to the protocol should be tracked and dated. The SPIRIT checklist is copyrighted by the SPIRIT

BMJ Open

Comparison of open- and closed-chain exercises in improving the response inhibitory ability of the elderly: a protocol for a randomized controlled clinical trial

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Complete List of Authors:	ke, liu; Shanghai Punan Hospital of Pudong New District lanlan, zhang; Guangzhou Sport University, School of Leisure Sport and Management jian, zhang; Shanghai University of Sport, School of Psychology jianing, wei; Shanghai University of Sport, School of Psychology
Primary Subject Heading:	Public health
Secondary Subject Heading:	Mental health, Public health
Keywords:	Old age psychiatry < PSYCHIATRY, MENTAL HEALTH, Biophysics < NATURAL SCIENCE DISCIPLINES, PUBLIC HEALTH

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Title: Comparison of open- and closed-chain exercises in improving the response inhibitory ability of the elderly: a protocol for a randomized controlled clinical trial

Article Type: Clinical Study Protocol

Keywords: Elder; Open-chain exercise; Closed-chain exercise; Response inhibitory ability; Study protocol

Corresponding Author: Jia-Ning Wei

Corresponding Author's Institution: Shanghai University of Sport

First Author: Ke Liu, Lan-Lan Zhang

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Abstract

Introduction As people age, they are more likely to experience a decline in their response inhibition ability, which interferes with daily life. Previous studies have shown that exercise intervention can improve the cognitive ability of the elderly, but research on open- and closed-chain exercises to improve the response inhibition in this age group is still limited. This study will explore the advantages of long-term intervention of table tennis (open-chain exercise) compared with fit aerobics (closed-chain exercise) on the response inhibitory ability of the elderly.

Methods and analysis A single-blind randomized controlled trial will be conducted. A total of 90 elderly subjects will be recruited and allocated randomly to the following groups: table tennis, fit aerobics, and control. The interventions for the table tennis group and the fit aerobics group will be implemented in three 60-min sessions

per week for 6 months; the control group will receive no exercise intervention. The primary assessment will be behavioral indicators of response inhibitory ability in the elderly based on the stop signal task (SST). The secondary outcomes will include cognitive ability, mental status, and depression in the elderly. Assessments will be conducted at baseline, 3 months, 6 months, and 12 months.

Ethics and dissemination This study was approved by the Shanghai University of Sport Research Ethics Committee (102772019RT012) and will provide reference for the advantages of table tennis compared with other types of sports in improving the response inhibitory ability of the elderly. The results of this study will provide a theoretical basis for choosing the best exercise program to improve the response inhibitory ability of the elderly.

Trial registration number This study has been registered prospectively in the Chinese Clinical Trial Registry (ChiCTR2100043616, 23 February 2021)

Title: Comparison of open- and closed-chain exercises in improving the response inhibitory ability of the elderly: a protocol for a randomized controlled clinical trial

Type of Manuscript: Clinical Study Protocol

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Abbreviations

SST, Stop signal task

SSRT, stop signal response time

SSD, stop signal delay

MoCA, Montreal Cognitive Assessment

BDI-II, Beck Depression Inventory (2nd edition);

MMSE, Mini Mental State Examination

Comparison of open- and closed-chain exercises in improving the response inhibitory ability of the elderly: a protocol for a randomized controlled clinical trial

Abstract

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Trial registration number This study has been registered prospectively in the Chinese Clinical Trial Registry (ChiCTR2100043616, 23 February 2021).

Strengths and limitations of this study

1. Because it is a sports intervention, the safety of the elderly during exercise is worth worrying about.
2. How to select and control participants in a longitudinal study is one of the difficulties of this project.
3. The patients will come from one geographic area which limits the generalisability.

Introduction

Response inhibition ability is a type of cognitive control ability that can achieve behavioral goals by adjusting perception and motor function in the changing environment as well as be used to solve conflicts.[1] As people age, they are likely to experience a decline in their response inhibition ability,[2-5] which can interfere with daily life and even the ability to live independently. Although some studies have shown that exercise intervention can improve the cognitive ability of the elderly,[6] there are few studies on the effect of exercise intervention on reactive inhibition

ability. In particular, research on the different types of exercise to improve the response inhibition ability of the elderly is still limited.

Sports can be divided into closed kinetic chain activities and open kinetic chain activities.[7] It is different from Open kinetic chain exercise (OKCE) and closed kinetic chain exercise (CKCE) in exercise prescription.[8] The open and closed mentioned here refer to the movement environment and movement methods, not the fixed point of the extremity during movements. The operating environment of closed-chain exercises, such as fit aerobics, fitness running, etc., is stable; and the operating state is determined by the operator. In contrast, the operating environment of open-chain exercises, including those involved in the sports of table tennis, basketball, etc., is unstable; and the operation state is determined by external conditions, such as a ball and opponents. In open-chain exercises, the participant must continuously adjust their behavior to unpredictable stimuli and must invest more cognitive resources in the decision-making process. Previous studies have shown that open-chain exercises require more regulating capacity than closed-chain exercises.[9] First, a study comparing the cognitive control of sports involving open-chain exercises with that of closed-chain exercises has revealed that athletes engaging in open-chain exercises have an advantage in cognitive control. It has been demonstrated that intervention with long-term open-chain exercise can improve cognitive function better than closed-chain exercise,[10] but whether it can improve response inhibitory ability better is not clear.

As one of the classical paradigms to test response inhibition, the stop signal

task (SST) tests the complete suppression of an ongoing action. The SST instructs the participant to perform a response when the go signal appears, but after a few go signals appear, a stop signal will appear at a specific time interval, and the individual will be asked to stop the response as far as possible.[11] The strengths of this test are that a stop signal to evoke controlling behavior is administered after a go signal is used, and the interval between these two signals dynamically changes regularly.[12] In addition, the SST is capable of quantizing inhibitory control behavior. However, no response occurs when the participant holds up successfully. The stop signal response time (SSRT) is a more sensitive indicator to evaluate the response inhibitory ability.[13] In short, to calculate the SSRT, all go-reactions (i.e., go-trials in which the response was missed) are rank-ordered and assigned the maximum response time in order to compensate for the lacking response. Afterwards, the most recent stop signal delay (SSD) is subtracted from the response time corresponding to the stop-signal response percentile. The resulting value is termed the SSRT.[14,15] These results can be used as an important index to evaluate the response inhibitory ability.

The proposed randomized clinical trial will examine the effects of table tennis (open-chain exercise) and fit aerobics (closed-chain exercise) on the primary outcome (behavioral task) of response inhibitory ability as well as on the secondary outcomes of cognitive ability, mental status, and depression in the elderly. We hypothesized that different types of exercise intervention can affect the response inhibitory ability to varying degrees and that the effect of open-chain exercises is better.

Methods

Study design

This study protocol of a study is designed as a prospective, single-blind randomized controlled trial. Eligible participants will be randomized into table tennis, fit aerobics, or control groups at a 1:1:1 ratio. The duration of exercise intervention will be 6 months. The cognitive function test (questionnaire and behavioral task) will be conducted before the intervention as well as at 3 months, 6 months, and 12 months after the intervention. Participants who meet the criteria will undergo baseline assessments. All evaluations will be done at baseline and immediately after the exercise intervention (See Figure 1). We will recruit healthy right-handed elderly participants with normal or corrected-to-normal vision and without a history of neurological diseases in the same way.The study is scheduled to begin in August 2021 and continue until August 2023.

Figure 1 Flow diagram of the study design

Participants

Any participants with heart disease, neurological disorder, musculoskeletal disorders, and other conditions not suitable for physical activity, contraindications to fMRI or TMS will be excluded. In addition, those with a regular exercise routine will be excluded. All participants will be between the ages of 60 and 70 years old and right-handed as assessed by the Edinburgh Handedness Inventory. Moreover, they must have their own residence.

Before and after the intervention, all groups will have their demographics statistically analyzed for factors such as health status, physical fitness, and cognitive function (Table 1). Intergroup differences will be minimized before the intervention.

Table 1 Demographic and clinical characteristics of the study participants

	Open group	Closed group	Control
Age			
Gender (male:female)			
Hight			
Body mass index (kg/m^2)			
HRmax			
Score for self-reported habitual physical activity			
MoCA			
BDI-II			
MMSE			
Behavioral tests for cognitive ability (RT)			
Behavioral test about cognitive ability (ACC)			

MoCA, Montreal Cognitive Assessment; BDI-II, Beck Depression Inventory (2nd edition); MMSE, Mini Mental State Examination; Behavioral tests for cognitive ability: Stroop task testing, n-back task testing, task-switch task testing; RT, response time; ACC, accuracy.

Sample size

From our previous studies on the modulation of SST performance,[16,17] we expected an effect of r = 0.4. Together with an α-value of 0.05 and a power of 1 – β = 0.9, a sample of at least 72 participants (24/group) was planned to find a similar effect. Calculations were carried out using G*Power, version 3.1,[18] with anticipation of a 20% attrition rate. Therefore, we plan to recruit 90 subjects (30/group).

Randomisation

Eligible participants will be randomized into table tennis, fit aerobics, or control groups at a 1:1:1 ratio after consenting and baseline assessment. We will use The Excel software to code the subjects in 1-90 according to the recruitment time, and then use the formula '=RAND()' to generate the corresponding random sequence. By sorting the random sequence and then grouping it, 90 subjects will be randomly grouped. The above tasks will be completed by professional computer workers after the participants are recruited. They are double-blind with recruitment and grouping.

Exercise intervention

The exercise intervention will last for 6 months. The participants will be divided into three groups: table tennis, fit aerobics, and control. The table tennis (open-chain) and fit aerobics (closed-chain) groups will train for 60 min, three times a week. The exercise intensity will be monitored, ensuring that the heart rate remains in the range of 60–70% of the maximum heart rate (HRMAX = 220 – age). During the training period, the exercise intensity will be monitored by the experimenter through real-time

heart rate monitoring and the subject's subjective reaction. The exercise load and heart rate responses of the subjects will be recorded at each training session and adjusted accordingly with an increase of aerobic capacity. All the participants are not used to regular exercise before participating in the experiment. The control group just needs to maintain their old habits, and we will visit the control group regularly to evaluate their physical activity, so as to ensure that their physical activity does not meet the exercise standards. The entire intervention process will be monitored in real time by health care professionals. We will have coaches to monitor and record their attendance, and if they are absent, they will supplement the training at other times. Specific intervention methods are shown in Table 2.

Table 2 Exercise intervention TIDieR

Item NO	Brief name	Group		
		Table tennis group	Fit aerobics group	Control group
1	Why	Table tennis	Fit aerobics	Control
2	What	Participants will be led by professional table tennis coaches for 6 months of table tennis exercise.	Participants will be led by professional fit aerobics coaches for 6 months of fit aerobics exercise.	Keep the original living habits, do not have regular exercise, regularly attend health lectures and accept telephone follow-up.
3	What (materials)	Participants will do 60 minutes of exercise three times a week. Specific exercises will be described later.		Participants will attend biweekly health talks and will be interviewed by phone once a month.
4	What (procedures)	Each participant received a test report before and at 3, 6, and 12 months after the start of the exercise so that they could understand their physical and psychological changes.		

5	Who provided	Table tennis coaches is the second level table tennis athlete in China from Shanghai University of Sport.The psychology-related tests were completed by ph. D. students majoring in psychology at Shanghai University of Sport.	Fit aerobics coaches is the second level fit aerobics athlete in China from Shanghai University of Sport.The psychology-related tests were completed by ph. D. students majoring in psychology at Shanghai University of Sport.	The health lecture was completed by ph. D. students majoring in physical Education and training in Shanghai University of Sport, and the telephone return visit was completed by ph. D. students majoring in psychology.
6	How	The exercise intervention will take place in a stationary gym, where the instructor will direct the whole group face to face.		Health lectures will be conducted face to face in a group format, and telephone return visits will be conducted one by one.
7	Where	Table tennis training is held in China Table Tennis College of Shanghai Sport University.There is a professional table tennis training ground.	Fit aerobic trianing is conducted in the School of Physical Education and Training of Shanghai Sport University. There is a professional aerobics training ground.	The health lecture will be held in the conference room of school of Psychology, Shanghai University of Sport.
8	When and how much	The table tennis (open-chain) and fit aerobics (closed-chain) groups will train for 60 min, three times a week. The exercise intensity will be monitored, ensuring that the heart rate remains in the range of 60–70% of the maximum heart rate (HRMAX = 220 – age). Each session will consist of a warm-up for 10 min, table tennis practice under the guidance of a coach for 40 min, and relaxation for 10 min. The degree of difficulty of training throughout the program will be gradually increased. Table tennis at 50–60% of the maximum heart rate for the first two weeks, followed by 60–70% of the maximum heart rate. The training will consist of the following seven main parts: (1) footwork; (2) the serve; (3)	The participants in the closed-chain exercise group will attend a supervised fit aerobics class of the same frequency, duration, and length as the open-chain exercise group. Fit aerobics at 50–60% of the maximum heart rate for the first two weeks, followed by 60–70% of the maximum heart rate. Each fit aerobics class will consist of warm-up activities for 10 min, basic aerobics activities for 40 min,, and relaxation and stretching for 10 min. The fit aerobics training will involve the	Fortnightly health lectures of 30-50 minutes will be held. A 10-minute return call once a month.

		forehand backhand attack; (4) forehand backhand loop; (5) kill shot; (6) continuous hitting of directional or nondirectional balls randomly sent by the server; and (7) comprehensive practice. All the technical movements will be from simple to complex.	following: 1) jogging, rope skipping, and/or gymnastics to warm up and achieve a slightly sweating body, and the heart rate will be slightly faster; 2) stepping, side parallel step, side cross step, jumping jacks, lunging, kicking, and so on. Following the rhythm of the music, each action will be reduced from four sets to two sets and then to one set; 3) relax the shoulder, elbow, hip, and knee joints by doing a few stretches to help relax the muscles.
9	Tailoring:	Exercise interventions were performed at 50-60% of maximum heart rate for the first two weeks, followed by 60-70% of maximum heart rate.In order to ensure the safety of participants, the exercise intensity will be gradually increased, and the first two weeks will be mainly acclimatization.	
10	How well (planned)	Feedback will be given to each participant on a regular basis, including their physical and psychological data, as well as their motor skills learning performance. Keep them up to date on their progress and status to keep them engaged.	

SST protocol

The SST was programmed using E-prime 2, in which the subjects will be asked to press a "←" button or a "→" button according to the left and right arrow directions. In 25% of the trials, the arrow will turn red and a gray triangle will appear; the participants will press the button to stop or give no response. The interval of stimulation will be dynamically adjusted according to the tracking procedure. The task will be divided into four groups of 120 trials each. The task flow is shown in Figure 2. The execution go signal reaction time (GoRT), stop response reaction time

(SRRT), SSD, and SSRT will be investigated. GoRT is how long it takes for the participant to respond after the GO (black arrow) appears.SRRT is the time to respond to the stop signal (arrow turning red) task.SSD is the time between the task stimulus and the stop signal.

Figure 2 Stop signal task flow chart

The instructions for the experiment will be follows: Welcome to the experiment. First, "+" will appear in the center of the screen to alert the user to begin the keystroke reaction, and the right index finger should be placed on the "↓" to prepare for the experiment. When the black arrow appears in the center of the screen, use your right index finger to press the button. When the left arrow appears, use your index finger to press the "←" key on the keyboard. When the right arrow appears, use your index finger to press the "→" key on the keyboard. After each key response, the right index finger should quickly return to the "↓" key to wait for the next response. When the black arrow in the center of the screen turns red and a small gray triangle appears, please stop the keystroke reaction immediately. When the red arrow appears in the center of the screen, please do not perform any keystroke reaction. Let's move on to practice.

Outcomes

Primary outcome

Behavioral task

The task will include randomly interspersed no-go and stop-signal trials, which will enable us to examine both types of inhibition. A total of 480 trials will be performed, including 75% go trials and 25% stop trials. On go trials, the subjects will respond to a left/right black arrow (1000 ms) by pressing the buttons with their right hand. Responses will be made with the index finger (for the left or right arrow). In the stop-signal trials, a response will be initially cued by a left/right black arrow, but the arrow color will change to red concurrent with a gray triangle after a SSD, and the subjects will be asked not to respond. The SSD will be varied from trial to trial by using a step-up/down algorithm with an initial estimate of 250 ms to maintain 50% successful inhibition. The task flow chart is shown in Figure 3.

Figure 3 Stop behavioral task

The task will consist of randomly interspersed no-go and stop-signal trials. A total of 480 trials will be performed (75% go, 25% stop).

Secondary outcomes

Secondary outcome measures will include the following: (1) Montreal Cognitive Assessment (MoCA); (2) BDI-II; (3) MMSE; (4) Stroop task testing; (5) n-back task testing; and (6) task-switch task testing (Table 3). The process of inhibitory control is the process of inhibition, refresh, and switching of the response task through cognitive

function, so we will test the abilities of inhibition, refresh, and switching in the cognitive process of the elderly with different exercise types before and after the intervention by the Stroop task, the n-back task, and the task-switch task to compare their response inhibitory ability. The details of each outcome and instrument will be compiled as in Table 3.

Table 3 The differences among the three groups of subjects at various stages

	Group	Baseline	6 months	12 months	18 months	24 months	F (P value) Time effect	F (P value) Group effect	F (P value) Interaction effect
MoCA	Open								
	Closed								
	Control								
BDI-II	Open								
	Closed								
	Control								
MMSE	Open								
	Closed								
	Control								
Stroop (RT)	Open								
	Closed								

	Control	
n-back (ACC)	Open	
	Closed	
	Control	
Task-switch (ACC)	Open	
	Closed	
	Control	

MoCA, Montreal Cognitive Assessment; BDI-II, Beck Depression Inventory (2nd edition); MMSE, Mini Mental State Examination; RT, response time; ACC, accuracy.

MoCA

The MoCA is an assessment tool for the rapid screening of cognitive dysfunction. It includes 11 items in 8 cognitive domains: attention and concentration, executive function, memory, language, abstract thinking, and computation.[19] The highest possible total score is 30, and a score of 26 or more is normal. It has a high sensitivity and a short test time, so it is suitable for clinical application.

BDI-II

The BDI-II contains 21 topics, which are suitable for people older than 13 years old. The areas of focus include symptoms of depression, such as despair, sensitivity, ways of understanding things, and physical characteristics, such as fatigue, weight loss, and decreased sexual ability.[20]

MMSE

The MMSE scale includes the following seven aspects: time orientation, place orientation, immediate memory, attention and calculation, delayed memory, language, and visual space.[21] There are a total of 30 questions asked in the exam, with 1 point awarded for each correct answer, and 0 points given for each wrong answer or unanswered question. The total score range of the scale is 0–30 points. The test scores are closely related to the educational level of the subject. The normal cut-off values are as follows: illiterate subjects, >17; primary school education only, >20; junior high school education and above, >24.

Stroop task

After a period of exercise intervention, comparison of the Stroop task response time between the open-chain, closed-chain, and control groups will be used to explore which types of exercise can improve cognitive inhibition ability[22].

N-back task

By comparing the n-back task accuracy of the elderly in the three groups, the improvement of the cognitive refresh ability of each group will be compared under different cognitive loads.[23]

Task-switch task

By comparing the task-switch accuracy of the three groups under different stimulus conditions, we will determine which type of exercise can improve the cognitive transformation ability most significantly.[24]

Patient and public involvement

Participants have not been involved in the study recruitment. The authors conceived the initial research questions and outcome measures, and modified according to the telephone interviews with patients and their guardians by a research assistant. In order to assure the safety and feasibility of the intervention, we invited six elderly peoples to learn and practise the table tennis and fit aerobics exercise before designing the RCT. Table tennis and fit aerobics exercise were revised based on the exercise performance and feedback provided by the participants. The burden of the intervention will be assessed by patients and their advisors through face-to-face interviews before signing informed consent. The findings of the study will be disseminated to the participants and their guardians.

Statistical analysis

The outcome assessor will be completed by the designated medical institution (Shanghai Punan Hospital of Pudong New District, Shanghai, China), when the participants go for the assessment, there will be no labels, so the outcome assessors will be blind the group allocation. In order to ensure no inter-group differences in all test indicators after random grouping, Independent-sample T test will be performed on

each pretest data after random grouping. Repeated-measures analysis of variance will be used to determine the effects of different types of exercise (open, closed, or control) on the primary outcomes (GoRT, SRRT, SSD, and SSRT) as well as on the secondary outcomes (MOCA score, BDI-II score, MMSE score, Stroop response time, n-back accuracy, task-switch accuracy), with group and time serving as factors. Data will be analyzed by PhD students who are blind to group allocation.

Discussion

Studies have found that elderly people who participate in ball and racket projects have higher health and physical awareness.[25] Pilates exercises decreased depression and improved the balance related to falling in elderly,[26] and also experienced significant improvement in physical, social spiritual, and emotional wellness.[27] Korean scholars found the cognitive/exercise dual-task program was an effective intervention for improving cognitive function, health status, and life satisfaction, and for decreasing depression of the elderly living in the community.[28]

Then some researchers found that athletes participating in open-chain exercises have a faster switching speed, fewer cognitive resources, and a higher efficiency in the inhibition process.[29] At the same time, another study has demonstrated that athletes who engage in open-chain exercises have a stronger reaction switching capability.[30] Based on previous research, participating in sports involving open-chain exercises can improve the ability of inhibition, refresh, and conversion in the inhibitory control process. In the Stoop task, when two different dimensions of a

stimulus interfere with each other, it is necessary for participants to inhibit the interfering stimulus, it looked at the participants' ability to suppress interference. In the n-back task, participants' attention capacity and memory capacity could be examined during the process of stimulus updating. In task-switch task, participants need to keep their attention focused when switching between different tasks, so it can investigate the transformation ability of participants in the cognitive process. Therefore, in this study, the Stroop task, n-back task, and task-switch task were selected as secondary outcomes to investigate the inhibition, refresh, and transformation abilities, respectively, of the participants. Determining the effect of long-term intervention of different types of sports on the response inhibitory ability of the elderly will improve our understanding of inhibitory control degradation and support the development of diversified training programs.

This study will use the SST to explore how different types of exercise experience affect the response inhibition ability in the elderly. Because of the interactions of the cognitive level, depressive state, and mental state with the response inhibitory ability, we will perform multiple MoCA, BDI-II, MMSE measurements before and after each intervention. We will also explore whether sports involving open-chain exercises can improve the cognitive level, depression state, and mental state of the elderly while improving their inhibition and control ability. Through multi-dimensional measurements of the participants, we hope to provide a more sufficient theoretical basis for the mechanism of improving the inhibition and control ability of the elderly through exercise.

This study will have several limitations. In this research, the screening principles of the subjects will be determined in the longitudinal study, and the inclusion criteria and exclusion criteria will be strictly defined, especially the experimental groups and the control group in terms of age, physical level, intervention time, and intensity. In addition, because the exercise that will serve as an intervention will be widely known to the participants, the single-blind design may expose the study to risks of bias stemming from performance and evaluation, which may potentially lead to overestimation of the effects of exercise.

Ethics and dissemination

All participants who meet the inclusion and exclusion criteria will be required to sign an informed consent form prior to enrolling in the study. This study was approved by the Shanghai University of Sport Research Ethics Committee (102772019RT012). Study findings will be disseminated via publications in peer-reviewed journals and presentations at international conferences.

Funding: This study was supported by grants from the National Natural Science Foundation of China (3197070657) .

Contributorship statement

Ke Liu: Conceptualization, Methodology, SoftwarePriya. Lanlan Zhang:Writing-

Reviewing and Editing. Jian Zhang: Visualization, Investigation. Jia-Ning Wei: Data curation, Writing- Original draft preparation.

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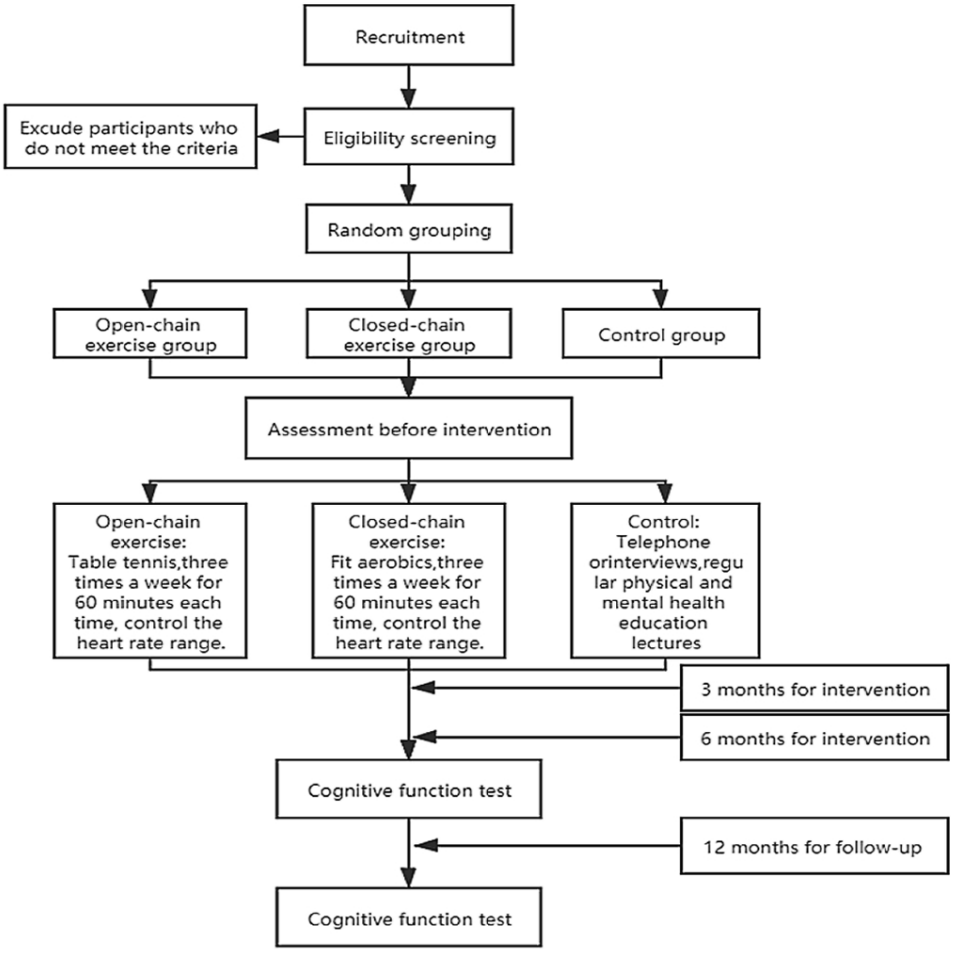

Figure 1 Flow diagram of the study design

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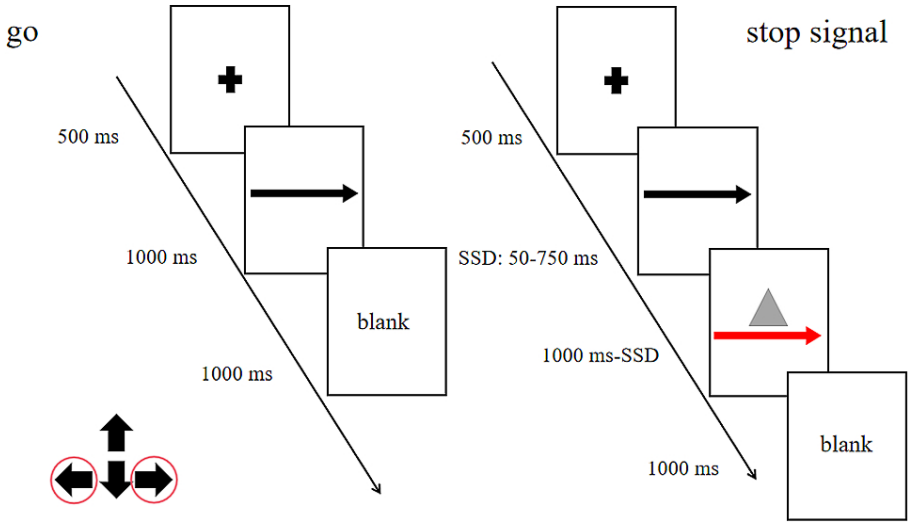

Figure 2. Stop signal task flow chart

90x90mm (300 x 300 DPI)

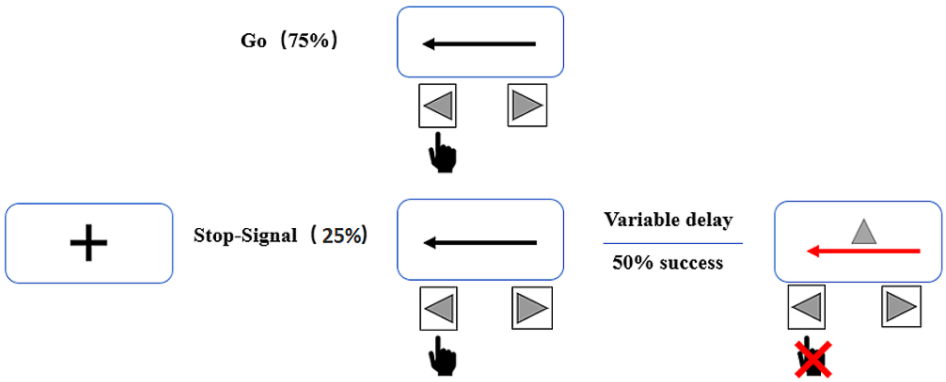

Figure 3. Stop behavioral task
The task will consist of randomly interspersed no-go and stop-signal trials. A total of 480 trials will be performed (75% go, 25% stop).

90x90mm (300 x 300 DPI)

SPIRIT
STANDARD PROTOCOL ITEMS: RECOMMENDATIONS FOR INTERVENTIONAL TRIALS

SPIRIT 2013 Checklist: Recommended items to address in a clinical trial protocol and related documents*

Section/item	Item No	Description
Administrative information		
Title	1	Comparison of open- and closed-chain exercises in improving the response inhibitory ability of the elderly: a protocol for a randomized controlled clinical trial（page 8,line 4）
Trial registration	2a	This study has been registered prospectively in the Chinese Clinical Trial Registry (ChiCTR2100043616, 23 February 2021).（page 9,line 17）
	2b	
Protocol version	3	The study is scheduled to begin in August 2021 and continue until August 2023.（page 12,line 40）
Funding	4	This study was supported by grants from the National Natural Science Foundation of China (3197070657) .（page 26,line 22）
Roles and responsibilities	5a	Ke Liu; Shanghai Punan Hospital of Pudong New District, Shanghai, China; Conceptualization, Methodology, SoftwarePriya. （page 26,line 30）
	5b	
	5c	
	5d	Lan-Lan Zhang: Writing- Reviewing and Editing. Jian Zhang: Visualization, Investigation. Jia-Ning Wei: Data curation, Writing-Original draft preparation.（page 26,line 30）
Introduction		
Background and rationale	6a	As people age, they are more likely to experience a decline in their response inhibition ability, which interferes with daily life. Previous studies have shown that exercise intervention can improve the cognitive ability of the elderly, but research on open- and closed-chain exercises to improve the response inhibition in this age group is still limited. This study will explore the advantages of long-term intervention of table tennis (open-chain exercise) compared with fit aerobics (closed-chain exercise) on the response inhibitory ability of the elderly.（page 8,line 17）

	6b	The elderly who choose not to exercise as the control group can compare the effects of exercise intervention with the intervention group.（page 15,line 21）
Objectives	7	We hypothesized that different types of exercise intervention can affect the response inhibitory ability to varying degrees and that the effect of open-chain exercises is better.（page 11,line 58）
Trial design	8	This study protocol of a pilot study is designed as a prospective, single-blind randomized controlled trial. Eligible participants will be randomized into table tennis, fit aerobics, or control groups at a 1:1:1 ratio. The duration of exercise intervention will be 6 months. The cognitive function test (questionnaire and behavioral task) will be conducted before the intervention as well as at 3 months, 6 months, and 12 months after the intervention. Participants who meet the criteria will undergo baseline assessments. All evaluations will be done at baseline and immediately after the exercise intervention.（page 12,line 17）
Methods: Participants, interventions, and outcomes		
Study setting	9	School of Psychology, Shanghai University of Sport, Shanghai, China（page 15,line 21）
Eligibility criteria	10	Any participants with heart disease, neurological disorder, musculoskeletal disorders, and other conditions not suitable for physical activity, contraindications to fMRI or TMS will be excluded. In addition, those with a regular exercise routine will be excluded. All participants will be between the ages of 60 and 70 years old and right-handed as assessed by the Edinburgh Handedness Inventory. Moreover, they must have their own residence.（page 12,line 53）
Interventions	11a	Table 2 Exercise intervention TIDieR（page 15,line 20）
	11b	Table 2 Exercise intervention TIDieR（page 15,line 20）
	11c	Table 2 Exercise intervention TIDieR（page 15,line 20）
	11d	Table 2 Exercise intervention TIDieR（page 15,line 20）

Outcomes	12	Primary outcome： Behavioral task（RT,ACC）Secondary outcome measures will include the following: (1) Montreal Cognitive Assessment (MoCA); (2) BDI-II; (3) MMSE; (4) Stroop task testing; (5) n-back task testing; and (6) task-switch task testing (Table 3). The process of inhibitory control is the process of inhibition, refresh, and switching of the response task through cognitive function, so we will test the abilities of inhibition, refresh, and switching in the cognitive process of the elderly with different exercise types before and after the intervention by the Stroop task, the n-back task, and the task-switch task to compare their response inhibitory ability. The details of each outcome and instrument will be compiled as in Table 3. （page 19,line 45）
Participant timeline	13	This study protocol of a pilot study is designed as a prospective, single-blind randomized controlled trial. Eligible participants will be randomized into table tennis, fit aerobics, or control groups at a 1:1:1 ratio. The duration of exercise intervention will be 6 months. The cognitive function test (questionnaire and behavioral task) will be conducted before the intervention as well as at 3 months, 6 months, and 12 months after the intervention. Participants who meet the criteria will undergo baseline assessments. All evaluations will be done at baseline and immediately after the exercise intervention (See Figure 1).（page 12,line 17）
Sample size	14	From our previous studies on the modulation of SST performance,we expected an effect of r = 0.4. Together with an α-value of 0.05 and a power of $1-\beta = 0.9$, a sample of at least 72 participants (24/group) was planned to find a similar effect. Calculations were carried out using G*Power, version 3.1, with anticipation of a 20% attrition rate. Therefore, we plan to recruit 90 subjects (30/group).（page 14,line 13）
Recruitment	15	All participants were recruited and counted through the School of Psychology, Shanghai Sport University, and intervened in Shanghai Sport University.（page 15,line 20）

Methods: Assignment of interventions (for controlled trials)

Allocation:

Sequence generation	16a	Eligible participants will be randomized into table tennis, fit aerobics, or control groups at a 1:1:1 ratio after consenting and baseline assessment.I will use The Excel software to code the subjects in 1-90 according to the recruitment time, and then use the formula '=RAND()' to generate the corresponding random sequence. By sorting the random sequence and then grouping it, 90 subjects will be randomly grouped.（page 14,line 29）

Allocation concealment mechanism	16b	Eligible participants will be randomized into table tennis, fit aerobics, or control groups at a 1:1:1 ratio after consenting and baseline assessment.I will use The Excel software to code the subjects in 1-90 according to the recruitment time, and then use the formula '=RAND()' to generate the corresponding random sequence. By sorting the random sequence and then grouping it, 90 subjects will be randomly grouped.（page 14,line 29）
Implementation	16c	Ke Liu will generate the allocation sequence, Jian Zhang will enrol participants, and Jian Zhang will assign participants to interventions.
Blinding (masking)	17a	The data is analyzed by specialized PhD students, they analyse the data be blind to group allocation.（page 23,line 48）
	17b	After the results are processed, the grouping can be announced.
Methods: Data collection, management, and analysis		
Data collection methods	18a	In order to ensure no inter-group differences in all test indicators after random grouping, Independent-sample T test will be performed on each pretest data after random grouping. Repeated-measures analysis of variance will be used to determine the effects of different types of exercise (open, closed, or control) on the primary outcomes (GoRT, SRRT, SSD, and SSRT) as well as on the secondary outcomes (MOCA score, BDI-II score, MMSE score, Stroop response time, n-back accuracy, task-switch accuracy), with group and time serving as factors.（page 23,line 32）
	18b	Feedback will be given to each participant on a regular basis, including their physical and psychological data, as well as their motor skills learning performance. Keep them up to date on their progress and status to keep them engaged.（page 17,line 17）
Data management	19	The data is analyzed by specialized PhD students.（page 23,line 48）
Statistical methods	20a	Repeated-measures analysis of variance will be used to determine the effects of different types of exercise (open, closed, or control) on the primary outcomes (GoRT, SRRT, SSD, and SSRT) as well as on the secondary outcomes (MOCA score, BDI-II score, MMSE score, Stroop response time, n-back accuracy, task-switch accuracy), with group and time serving as factors.（page 23,line 38）
	20b	No
	20c	The data is analyzed by specialized PhD students, they analyse the data be blind to group allocation.（page 23,line 48）
Methods: Monitoring		
Data monitoring	21a	The data is analyzed by specialized PhD students, they analyse the data be blind to group allocation.（page 23,line 48）

	21b	The initiator of the experiment, Professor Zhang will have access to these interim results and make the final decision to terminate the trial
Harms	22	In the Participants gave an informed consent form.
Auditing	23	In the Participants gave an informed consent form.
Ethics and dissemination		
Research ethics approval	24	This study was approved by the Shanghai University of Sport Research Ethics Committee (102772019RT012).（page 8,line 59）
Protocol amendments	25	Upload as attachment.
Consent or assent	26a	PhD students in charge of data collection will collect data within the cognitive function test (questionnaire and behavioral task) will be conducted before the intervention as well as at 3 months, 6 months, and 12 months after the intervention.（page 12,line 24）
	26b	No
Confidentiality	27	Professor Zhang, who is in charge of recruitment, completes the participant information management.
Declaration of interests	28	The authors have no conflicts of interest to declare.
Access to data	29	The result will be made public by the person in charge of the National Natural Science Foundation of China (3197070657)
Ancillary and post-trial care	30	In the Participants gave an informed consent form.
Dissemination policy	31a	This study has been registered prospectively in the Chinese Clinical Trial Registry (ChiCTR2100043616, 23 February 2021).It will be published in accordance with the standards of the Chinese Clinical Trial Registry.
	31b	It will be written in accordance with the standards of the Chinese Clinical Trial Registry.
	31c	It can be viewed in the Chinese Clinical Trial Registry.
Appendices		
Informed consent materials	32	Upload as attachment.
Biological specimens	33	No.

*It is strongly recommended that this checklist be read in conjunction with the SPIRIT 2013 Explanation & Elaboration for important clarification on the items. Amendments to the protocol should be tracked and dated. The SPIRIT checklist is copyrighted by the SPIRIT