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Research article

The effect of different exercise on physical fitness, cognition, and mental health in healthy older adults

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ABSTRACT

Objective: This study aimed to examine the effects of different exercise programs on physical fitness, cognition, and mental health in healthy older adults.
Methods: A randomized controlled study was performed with 89 healthy older adults. They were separated into four groups: the control (Con; n = 20), physical activity (PA; n = 23), cognitive training (CT; n = 23), and physical activity coupled with cognitive training groups (PA + CT; n = 23). The subjects in PA, CT, and PA + CT groups received exercise programs that lasted 40 min daily, conducted at least three days a week for 20 weeks. The PA group received regular aerobic physical activity interventions, the CT group received cognitive training interventions, and the PA + CT group received physical activity combined with cognitive training interventions. Physical fitness (by chair stand, biceps curl, 2-min step, 8-step up and walk, and sit and reach tests), cognitive function (attention, simple reaction time, and spatial memory), and mental health (anxiety and depression status) were evaluated before and after 20 weeks.
Results: The body composition results reveal no significant effects among the four groups after 20 weeks before and after aerobic exercise interventions ($p > 0.05$). Compared with Con, the PA, CT, and PA + CT groups significantly improved physical fitness parameters ($p < 0.05$). The post-hoc analysis demonstrated that the PA and PA + CT groups had higher fitness levels than the CT group. Similarly, a significant difference was observed in the cognitive index among the four groups ($p < 0.05$). As determined by post-hoc analysis, attention and simple reaction time differed sequentially between the Con, PA, CT, and PA + CT groups. The spatial memory was superior in the PA, CT, and PA + CT groups compared to the Con group ($p < 0.05$), with the PA + CT group exhibiting the highest level of performance. However, there was no significant difference in the mental health parameters among all the groups ($p < 0.05$).
Conclusion: A 20-week intervention involving different exercise methods can enhance physical fitness, cognition, and mental health in older adults. These methods include physical activity, cognitive training, and a combination of physical and cognitive training. The combined physical activity and cognitive training interventions yielded more favorable outcomes than individual physical or cognitive training interventions.

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1. Introduction

The world's population is gradually aging, an inevitable process for all living creatures. Aging is a natural developmental process in which older people experience physical and psychological changes, which the following three aspects can illustrate. First, aging tends to decrease muscle mass and increase sedentary behavior, declining health-related quality of life and physical fitness, such as muscle strength, speed sensitivity, and flexibility [1,2]. Second, brain health is related to cognitive function. It is reported that larger cerebellar volume, especially cerebellar gray matter volume, positively affects global cognition, executive function, information processing speed, and motor speed [3]. Inversely, degenerative changes in the brain morphology and function tend to increase the risk of cognitive impairment and even dementia in older adults under normal or disease status [4]. Third, mental health problems among the older groups are also getting worse. Due to their vulnerability and disadvantage, older individuals may sometimes have a compromised and low quality of life, making them more susceptible to mental illness [5], and the decline of physical fitness and cognitive function can also exert a negative effect on their mental health [6]. Increased life expectancy does not necessarily indicate an enhancement in the quality of life. Specifically, older individuals with pre-existing medical conditions are more prone to experiencing health issues such as depression and anxiety [7]. In short, aging is associated with a decline in physical and cognitive functioning and mental health in older individuals. Thus, there is a need to find effective interventions to achieve proactive healthcare and prevent or delay the decline of physical and mental function in healthy older individuals.

A growing body of literature states that exercise is linked to physical and mental health improvement [8–10]. Aerobic exercise has a significant effect on cardiovascular function [11], muscle mass [12], balance, and flexibility [13] in older adults, with low to medium-intensity exercise more suitable and effective for them. In addition, a study found that healthy older adults who exercised regularly had a significantly lower risk of developing dementia than those who did not exercise regularly [14]. The findings also suggest that exercise can help delay cognitive decline in individuals with Alzheimer's disease, particularly in episodic memory and executive functions [15]. Furthermore, regular exercise and/or spontaneous physical activity contribute to health-related physical fitness and cognition, offering psychological and physical advantages and a protective barrier against stress and anxiety [16,17]. In recent years, numerous studies reporting the positive effect of various exercise types on older individuals compared to non-exercise individuals have been published, such as Tai-Chi [18], aquatic/general floor gymnastics [19], deep-water-running exercise [20], home-based exercise program [21], and computerized cognitive training [22]. However, there have only been a few studies comparing the effects of different exercises on older adults and exploring the optimal form of exercise.

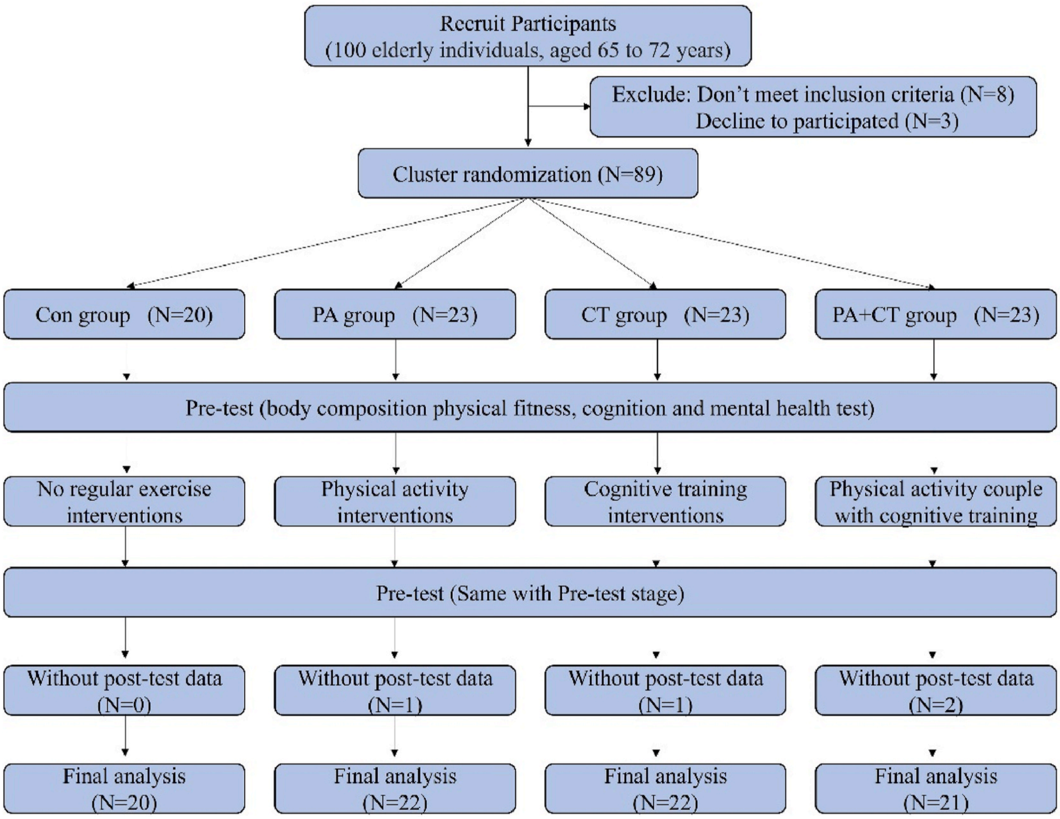

Fig. 1. Diagram of the sample selection process in this experiment (Con, control group; PA, physical activity group; CT, cognitive training group; and PA + CT, physical activity group coupled with cognitive training group).

Therefore, in the present study, we designed a 20-week randomized clinical trial to demonstrate the impact of different exercise interventions on physical fitness, cognition, and mental health in older people. We hypothesized that three different types of exercise interventions would play a better role in improving physical fitness, cognitive and mental function of older adult, including physical activity, cognitive training, physical activity coupled with cognitive training groups.

2. Materials and methods

2.1. Experiment design and participants

Initially, 100 healthy older adults from China were enrolled in this study. The inclusion criteria are: 1) All the participants are aged between 65 and 75 years; 2) Have no history of neuropsychological (including dementia/Parkinson's disorder) or physical problems; 3) No history of surgery or drugs in the past year; 4) Should not participate in other organized exercises; 5) The elderly individuals in this study have similar income. Eight adults did not meet the inclusion criteria, and three declined to participate. Thus, 89 healthy older individuals were included in the study and randomly divided into control (Con, n = 20), physical activity (PA, n = 23), cognitive training (CT, n = 23), and physical activity group coupled with cognitive training groups (PA + CT, n = 23). The individuals in the PA, CT, and PA + CT groups received exercise interventions (50 min/day, 3 to 5 times a week for 20 weeks). Regular aerobic physical activity in the PA group, cognitive training in the CT group, and physical activity coupled with cognitive training in the PA + CT group. Finally, 85 subjects finished the experiment, and their results were considered effective samples (Con, n = 20; PA, n = 22; CT, n = 22; PA + CT, n = 21; Fig. 1). Written informed consents were obtained from the participants. The study was approved by the institutional ethical committee of Shanghai University of Spor (No.102772021RT001).

2.2. Difference exercise interventions

The participants in the PA, CT, and PA + CT groups were informed to participate in at least three (of the five offered) supervised exercise sessions (50 min per session) per week for 20 weeks. Each 50-min session was divided into a warm-up period (5 min), the main training program (40 min), and a cool-down period (5 min). Exercise intensity was measured by a heart rate monitor and maintained at low intensity (50–60 % of the maximum HR).

2.3. Descriptive characteristics in each group at the baseline stage

Baseline characteristics were measured using a Holtain stadiometer and Inbody J10 (Biospace Corp., Seoul, Korea), evaluating the body weight (kg) and height (cm). The weight was measured to the closest 0.1 kg, and the height was measured to the closest 0.1 cm. The body mass index (BMI) was determined by dividing the weight in kilograms by height in meters squared (kg/m^2).

2.4. Physical fitness tests

A senior fitness test battery was used to evaluate the physical fitness [23].

The Chair Stand Test: The number of times a participant stood up and sat in a chair as soon as possible for 30 s was recorded as a score to assess lower limb muscle strength. The test used a standard-height chair (about 50 cm) with no armrests.

The Biceps Curl Test: To assess upper limb muscle strength, we measured the number of repetitions completed by the dominant arm from full extension to full flexion in 30 s. The participants were instructed to use a dumbbell (1.5 kg for women and 2.5 kg for men) to finish the test.

A 2-Minute Step Test: The participants were required to walk rapidly for 2 min, and the number of steps completed was recorded to determine their aerobic endurance.

Step Up and Walk exam: This exam evaluated agility and dynamic balance. The participants sat erect in the chair, with a water bottle placed 2.5 m away. The participant walked quickly between the water bottle and the chair, and the instructor timed the test.

Sit and Reach Test: This test assessed the flexibility of the lower limbs. The participants were instructed to sit on the floor with outstretched legs. They extended their torso forward without bending the knee in extension, reaching for their toes with both hands. The distance was measured in this test.

2.5. Cognitive function tests

Cognition was evaluated by attention, simple reaction, and spatial memory tests [24]. First, the Schulte scale was used to assess attention. In a 3 × 3 square, the numbers from 1 to 9 were randomly arranged. The subjects were instructed to rank the numbers from 1 to 9, and the time spent was recorded; the shorter, the better. If the click order was incorrect, the system prompted an error until the correct order was found. Second, the simple reaction test reflected the subject's ability to react quickly. During the test, participants should press the green button as soon as possible when the green circle appears in the middle of the screen. The participants were tested 30 times with a 2 s interval. Third, the spatial memory test tests their spatial orientation perception and short-term memory. During the test, a 5 × 3 grid was displayed on the computer screen. Pictures of animals would randomly appear in the grid and disappear immediately. The participants should click on the grid where the animals appear in the order they appear.

2.6. Mental health tests

Anxiety and depression were evaluated by the Beck Anxiety Inventory (BAI) and Beck Depression Inventory (BDI), respectively [25]. BAI comprises 21 inquiries regarding symptoms of anxiety, and the subjects select their responses based on their specific circumstances. The results include “1”–“no,” “2”–“mild,” “3”–“moderate,” and “4” representing “severe.” A higher total score meant a higher level of anxiety. Similar to the BAI, BDI also contains 21 questions, mainly reflecting the individual’s depression level. The higher the score, the higher the level of depression.

2.7. Statistical analyses

We examine both between-subject effects (differences between children in the intervention condition and the control condition) and within-subject effects (changes over time) in order to determine the efficacy of various exercise program types. The within-subject variable, "time," has two levels: the pre-test and the post-test. The between-subject variable called "condition" has two levels: intervention condition and control condition. All the data are presented as mean ± standard deviations (SDs). Prior to analysis, the raw data from all variables in this experiment will be checked for normality. And then, the SPSS 22.0 and GraphPad Prism 8.0 were used to conduct statistical procedures. The principal design for the analyses will be repeated-measures analysis of variance (ANOVA) using mixed models. The statistical significance value was described as $p < 0.05$.

3. Results

3.1. Descriptive baseline characteristics in each group

The baseline characteristics of each group are presented in Table 1. The results showed no significant difference at baseline stage—age, height, weight, and BMI of each group ($p > 0.05$). Baseline characteristics indicated that the subjects who underwent different exercise interventions did not differ in age, height, weight, or BMI from the participants who did not participate.

3.2. Effect of different exercise interventions on physical fitness in each group

Fig. 2 presents the results of the effects of different exercise interventions. A 4x2 repeated-measures ANOVA was performed on the chair stand test, the biceps curl test, the 2-min step test t, the step up and walk exam, and the sit and reach, with the intervention methods as a between-group factor and time as a within-group factor.

For the chair stand test, these results showed a significant main effect of intervention methods [$F_{(3,81)} = 11.142$, $p < 0.001$, $\eta^2_{partial} = 0.292$], and a significant main effect of time, Greenhouse-Geisser adjusted [$F_{(1, 81)} = 53.505$, $p < 0.001$, $\eta^2_{partial} = 0.398$], there was significant dosage × time interaction effect, Greenhouse-Geisser adjusted [$F_{(3, 81)} = 4.876$, $p = 0.004$, $\eta^2_{partial} = 0.153$]. Significant differences were found pre- and post-test in groups PA (Fig. 2A; $p < 0.001$), CT(Fig. 2A; $p = 0.003$), and PA + CT (Fig. 2A; $p < 0.001$). At post-test, the PA and PA + CT groups were significantly higher than the Con group and significantly higher than the CT group (Fig. 2A; PA vs. Con: $p < 0.001$) (Fig. 2A; PA + CT vs. Con: $p < 0.001$) (Fig. 2A; PA vs. CT: $p = 0.003$). (PA + CT vs. CT: $p < 0.001$).

For the biceps curl test, these results showed a significant main effect of intervention methods [$F_{(3,81)} = 11.142$, $p < 0.001$, $\eta^2_{partial} = 0.292$], and a significant main effect of time, Greenhouse-Geisser adjusted [$F_{(1, 81)} = 53.505$, $p < 0.001$, $\eta^2_{partial} = 0.398$], there was significant dosage × time interaction effect, Greenhouse-Geisser adjusted [$F_{(3, 81)} = 4.876$, $p = 0.004$, $\eta^2_{partial} = 0.153$]. Significant differences were found pre- and post-test in groups PA (Fig. 2B; $p < 0.001$), CT(Fig. 2B; $p < 0.001$), and PA + CT(Fig. 2B; $p < 0.001$). At post-test, the PA and PA + CT groups were significantly higher than the Con group and significantly higher than the CT group. (Fig. 2B; PA vs. Con: $p < 0.001$) (Fig. 2B; PA + CT vs. Con: $p < 0.001$)(Fig. 2B; PA vs. CT: $p = 0.005$) (Fig. 2B; PA + CT vs. CT: $p = 0.004$).

For the 2-min step test, these results showed a significant main effect of intervention methods [$F_{(3,81)} = 6.785$, $p < 0.001$, $\eta^2_{partial} = 0.201$], and a significant main effect of time, Greenhouse-Geisser adjusted [$F_{(1, 81)} = 35.026$, $p < 0.001$, $\eta^2_{partial} = 0.302$], there was not significant dosage × time interaction effect, Greenhouse-Geisser adjusted [$F_{(3, 81)} = 2.391$, $p = 0.075$, $\eta^2_{partial} = 0.081$]. Significant differences were found pre- and post-test in groups PA (Fig. 2C; $p < 0.001$) and PA + CT(Fig. 2C; $p < 0.001$). At post-test, the PA and PA + CT groups were significantly higher than the Con group (Fig. 2C; PA vs. Con: $p < 0.001$) (Fig. 2C; PA + CT vs. Con: $p < 0.001$).

For the step up and walk exam, these results showed a significant main effect of intervention methods [$F_{(3,81)} = 3.923$, $p = 0.011$, $\eta^2_{partial} = 0.127$], and a significant main effect of time, Greenhouse-Geisser adjusted [$F_{(1, 81)} = 120.811$, $p < 0.001$, $\eta^2_{partial} = 0.599$],

Table 1
Descriptive general characteristics in each group at baseline.

	Con	PA	CT	PA + CT
Age [year]	9.74 ± 0.43	9.61 ± 0.41	9.55 ± 0.37	9.6 ± 0.37
Height [cm]	137.72 ± 1.37	137.77 ± 0.96	137.68 ± 1.22	137.84 ± 1.15
Weight [kg]	30.85 ± 1.49	30.64 ± 1.50	30.59 ± 1.19	30.60 ± 1.26
BMI [kg/m^2]	16.27 ± 0.8	16.15 ± 0.78	16.14 ± 0.71	16.11 ± 0.74

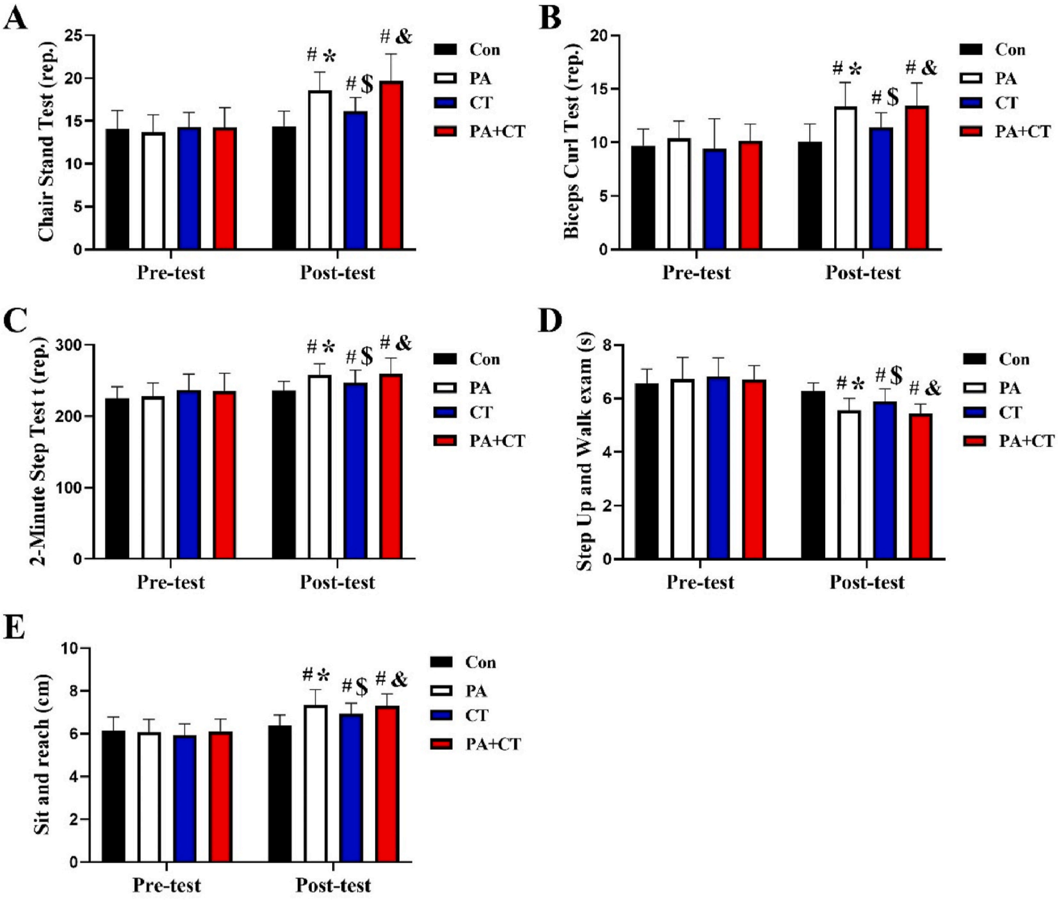

Fig. 2. Effects of different exercise interventions on physical fitness parameters in older adults. (A) vital capacity, (B) sit and reach, (C) 50m run, (D) rope skipping, and (E) sit-up. $^{\#}p < 0.05$ represents compared to Con in the post-test stage. $^{*}p < 0.05$ represents pre-test vs. post-test in the PA group. $^{\&}p < 0.05$ represents pre-test vs. post-test in the PA + CT group.

there was significant dosage × time interaction effect, Greenhouse-Geisser adjusted [$F_{(3,\ 81)} = 6.689$, $p < 0.001$, $\eta^2_{partial} = 0.199$]. Significant differences were found pre- and post-test in groups PA (Fig. 2D; $p < 0.001$), CT(Fig. 2D; $p < 0.001$), and PA + CT(Fig. 2D; $p < 0.001$). At post-test, the PA, CT, and PA + CT groups were significantly lower than the Con group. And the PA and PA + CT groups were significantly lower than the CT group. (Fig. 2D; PA vs. Con: $p < 0.001$)(Fig. 2D; CT vs. Con: $p = 0.022$) (Fig. 2D; PA + CT vs. Con: $p < 0.001$)(Fig. 2D; PA vs. CT: $p = 0.039$) (Fig. 2D; PA + CT vs. CT: $p = 0.002$).

For the sit and reach, these results showed a significant main effect of intervention methods [$F_{(3,81)} = 6.245$, $p < 0.001$, $\eta^2_{partial} = 0.188$], and a significant main effect of time, Greenhouse-Geisser adjusted [$F_{(1,\ 81)} = 100.568$, $p < 0.001$, $\eta^2_{partial} = 0.554$], there was significant dosage × time interaction effect, Greenhouse-Geisser adjusted [$F_{(3,\ 81)} = 6.317$, $p < 0.001$, $\eta^2_{partial} = 0.190$]. Significant differences were found pre- and post-test in groups PA (Fig. 2E; $p < 0.001$), CT(Fig. 2E; $p < 0.001$), and PA + CT(Fig. 2E; $p < 0.001$). At post-test, the PA, CT, and PA + CT groups were significantly higher than the Con group. (Fig. 2E; PA vs. Con: $p < 0.001$)(Fig. 2E; CT vs. Con: $p = 0.024$) (Fig. 2E; PA + CT vs. Con: $p < 0.001$).

3.3. Effect of different exercise interventions on cognition in each group

Fig. 4 shows the effect of different exercise interventions on cognition in each group. A 4x2 repeated-measures ANOVA was performed on the attention, the simple reaction time, and the spatial memory, with the intervention methods as a between-group factor and time as a within-group factor.

For the attention, these results showed a significant main effect of intervention methods [$F_{(3,80)} = 23.314$, $p < 0.001$, $\eta^2_{partial} = 0.466$], and a significant main effect of time, Greenhouse-Geisser adjusted [$F_{(1,\ 80)} = 138.769$, $p < 0.001$, $\eta^2_{partial} = 0.634$], there was significant dosage × time interaction effect, Greenhouse-Geisser adjusted [$F_{(3,\ 80)} = 21.305$, $p < 0.001$, $\eta^2_{partial} = 0.444$]. Significant differences were found pre- and post-test in groups PA (Fig. 3A; $p < 0.001$), CT(Fig. 3A; $p < 0.001$), and PA + CT(Fig. 3A; $p < 0.001$). At post-test, the PA, CT, and PA + CT groups were significantly lower than the Con group. The CT and PA + CT groups were significantly lower than the PA group (Fig. 3A; PA vs. Con: $p < 0.001$)(Fig. 3A; CT vs. Con: $p = 0.024$) (Fig. 3A; PA + CT vs. Con: $p < 0.001$) (Fig. 3A;

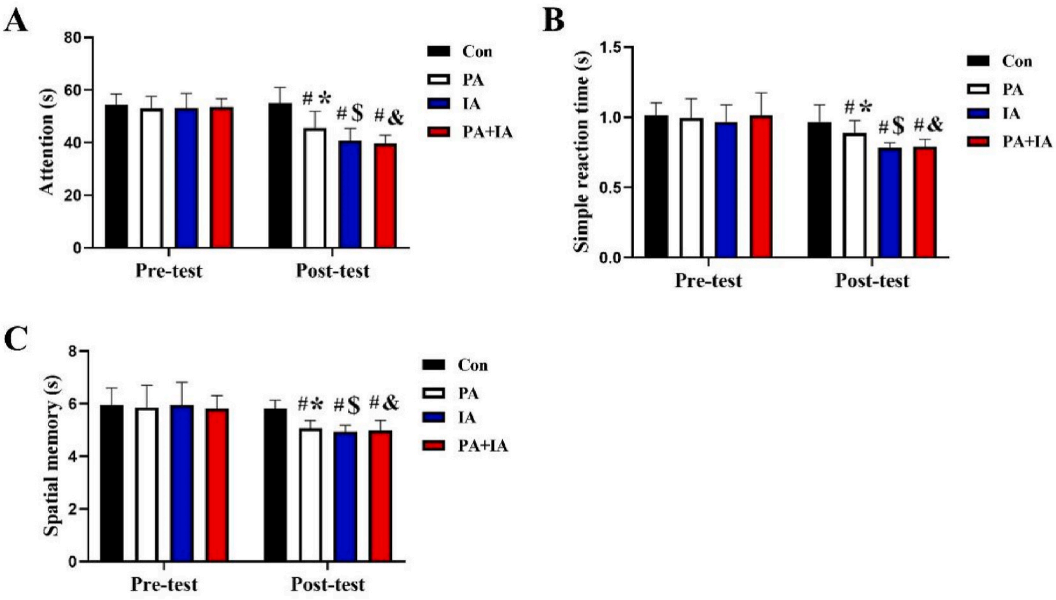

Fig. 3. Effects of different exercise interventions on cognitive parameters in older adults. (A) attention, (B) simple reaction time, and (C) spatial memory. $^{\#}p < 0.05$ represents the values compared to Con in the post-test stage. $^{*}p < 0.05$ represents pre-test vs. post-test in the PA group. $^{\$}p < 0.05$ represents the pre-test vs. post-test in the CT group. $^{\&}p < 0.05$ represents pre-test vs. post-test in the PA + CT group.

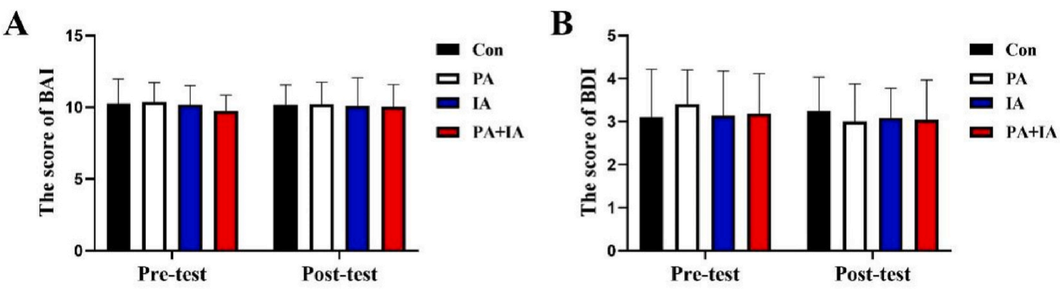

Fig. 4. Effects of different exercise interventions on mental health in older adults. (A) the score of BAI, (B) the score of BDI.

CT vs. PA: p = 0.014). (PA + CT vs. PA: p = 0.002).

For the simple reaction time, these results showed a significant main effect of intervention methods [$F_{(3,81)} = 7.687$, $p < 0.001$, $\eta^2_{partial} = 0.222$], and a significant main effect of time, Greenhouse-Geisser adjusted [$F_{(1, 81)} = 83.302$, $p < 0.001$, $\eta^2_{partial} = 0.507$], there was significant dosage × time interaction effect, Greenhouse-Geisser adjusted [$F_{(3, 81)} = 6.552$, $p < 0.001$, $\eta^2_{partial} = 0.195$]. Significant differences were found pre- and post-test in groups PA (Fig. 3B; p < 0.001), CT(Fig. 3B; p < 0.001), and PA + CT(Fig. 3B; p < 0.001). At post-test, the PA, CT, and PA + CT groups were significantly lower than the Con group. The CT and PA + CT groups were significantly lower than the PA group. (Fig. 3B; PA vs. Con: p = 0.009)(Fig. 3B; CT vs. Con: p = 0.024)(Fig. 3B; PA + CT vs. Con: p < 0.001) (Fig. 3B; CT vs. PA: p < 0.001) (Fig. 3B; PA + CT vs. PA: p = 0.002).

For the spatial memory, these results showed a significant main effect of intervention methods [$F_{(3,81)} = 7.182$, $p < 0.001$, $\eta^2_{partial} = 0.210$], and a significant main effect of time, Greenhouse-Geisser adjusted [$F_{(1, 81)} = 62.849$, $p < 0.001$, $\eta^2_{partial} = 0.437$], there was significant dosage × time interaction effect, Greenhouse-Geisser adjusted [$F_{(3, 81)} = 4.718$, $p = 0.004$, $\eta^2_{partial} = 0.149$]. Significant differences were found pre- and post-test in groups PA (Fig. 3C; p < 0.001), CT(Fig. 3C; p < 0.001), and PA + CT (Fig. 3C; p < 0.001). At post-test, the PA, CT, and PA + CT groups were significantly lower than the Con group (Fig. 3C; PA vs. Con: p < 0.001)(Fig. 3C; CT vs. Con: p < 0.001) (Fig. 3C; PA + CT vs. Con: p < 0.001).

However, while the impact on physical fitness varied among different exercise interventions, the exercise interventions influenced all cognitive parameters of the four groups. Overall, the exercise intervention had the greatest effects on the CT and PA + CT groups.

3.4. *Effect of different exercise interventions on mental health in each group*

Intragroup comparison from Fig. 4 revealed no significant difference in the scores of BAI and BDI in the mental health test before and after the experiment in the Con group (Fig. 4A–B; $p > 0.05$). This can also be found in the remaining groups, including the PA, CT, and PA + CT groups (Fig. 4A–B; $p > 0.05$).

Fig. 4 also indicates that there were no significant differences in any of the mental health variables between the periods and the groups. There was no statistically significant difference in mental health parameters among each group in the pre-test stage (Fig. 4A–B; $p > 0.05$), and this phenomenon is also observed in the post-test stage (Fig. 4A–B; $p > 0.05$).

4. Discussion

This study is the first randomized controlled trial with enough participants to investigate the effects of a 20-week physical exercise intervention on physical fitness, cognitive function, and mental health in older adults. The assumption is that various exercise interventions, such as physical activity, cognitive training, and physical activity coupled with cognitive training, lead to enhancements in physical fitness, cognitive function, and mental health. Moreover, we further hypothesized that the positive effect of physical activity with cognitive training is better than the other two interventions. To prove our hypothesis, we collected information on the older adults in each group before and after a 20-week exercise intervention, such as physical fitness (chair stand, biceps curl, 2-min step, step up and walk, and sit and reach tests), cognitive function (attention, simple reaction time and spatial memory), and mental health indices (anxiety and depression status).

We first collected baseline characteristics information from each group, such as age, height, weight, and BMI. The results of the baseline characteristics demonstrated that there were no significant differences in body morphology at the pre-test stage. The results indicated that the older adults who took part in the different exercise interventions did not differ in age, height, weight, or BMI from the ones who did not, avoiding the influence of baseline characteristics on subsequent experimental results.

Significant improvements in the physical fitness test were observed in the PA, CT, and PA + CT groups, as indicated by the pre- and post-test values. Consistent with previous studies, intention-to-treat analyses by Galle SA et al. [26] demonstrated that healthy older adults who increased their physical activity by 35 % or more had significant improvements in balance, lower body strength, and gait speed. Intergroup comparison in our study revealed significant improvement in physical fitness among the PA, CT, and PA + CT groups in the post-test stage compared to the Con group. This confirms the effect of positive improvements of different exercise interventions in healthy older adults. Our study also demonstrated that the positive effects of exercise intervention were more significant in the PA and PA + CT groups than in the CT group. Cognitive training primarily involves mental activity, and a 20-week cognitive training program may not substantially impact the physical fitness of healthy older adults. The data supported the idea that all different exercise interventions mentioned in our study can improve physical fitness status in older individuals, and the most effective exercise methods are simple physical activities or physical activities coupled with cognitive training.

We then explored the effect of various exercise interventions on the cognitive function of healthy older individuals. The findings showed that 20 weeks of multiple exercises, including physical activity, cognitive training, and physical activity combined with cognitive training, could all help the cognitive function of older adults. Numerous studies have demonstrated that exercise enhances brain health [27] and cognition function [28] and reduces the risk of dementia by 28 % [29] in the older population. Many studies reported the beneficial effects of physical activity [30,31] or cognitive training [32,33] on cognitive function in older adults. However, only a few studies combined both interventions and compared the type of exercise that is most effective. Our study is the first to demonstrate the beneficial effects of physical activity with cognitive training are better than only physical fitness interventions or cognitive training. However, Hao et al. [34] demonstrated that physical training with or without cognitive training can promote cognition in children aged 4–5. We hypothesized that different exercise intensities and subjects would yield distinct experimental outcomes.

Finally, the influence of different exercise interventions on mental health in the older population was also discussed. Available data suggest that physical activity [35] and cognitive treatment [36] positively affect the mental health of older individuals. Moreover, exercise has several beneficial effects on mental health in older adults. For instance, exercise helps to avoid mental issues by promoting neuronal plasticity, reducing sleep disturbances in adults with insomnia [37], reducing depression and anxiety [38], and improving happiness [39] in depressed individuals. In contrast, the findings of our study on mental health tests indicated that there were no notable disparities in the BAI and BDI scores before and after the exercise interventions within each group. It indicated that 20 weeks of different exercise interventions did not improve the mental health status of the participants. We believe that older people who meet the inclusion criteria for this study do not have mental health issues at baseline. Moreover, exercise can significantly improve mental health in older adults with cancer [40] or depression [41].

This data suggests that three different exercise interventions can improve physical fitness, cognition, and mental health in the older population. This suggests that engaging in regular physical activity, which improves fitness, may impact people's cognitive abilities in the future, giving them a chance to regulate their mental health [42]. However, this study still has many limitations. First, the sample size of each group needs to be expanded to sufficiently demonstrate the positive effects of different exercises on healthy older individuals. Second, other forms of exercise must be widespread among older people, such as mindfulness training and computer-based cognitive treatment. Third, to test the positive effect of exercise on the older population, future randomized controlled trials should also include outcome measures such as diet, education levels, sedentary time, and health-related quality of life to validate the findings.

5. Conclusion

Therefore, in this randomized clinical trial including older adults, we can deduce that various exercise interventions lasting 20 weeks can enhance physical fitness, cognition, and mental health in older individuals. These interventions include physical activity, cognitive training, and a combination of physical and cognitive training. Furthermore, physical activity couple with cognitive training was found to be more effective than single physical activity or cognitive training at improving global physical fitness, cognition, and mental health to some extent. The findings support a long-term benefit of physical activity couple with cognitive training in strengthening physical and mental health, supporting the clinical application of physical activity couple with cognitive training as an effective exercise intervention to promote physical and mental health for older adult.

Data availability

All relevant data in this study can be obtained from the first author on request.

CRediT authorship contribution statement

Qiangqiang Xu: Writing – original draft, Software, Methodology, Conceptualization. **Yongzhao Fan:** Writing – original draft, Methodology, Investigation, Data curation. **Jianghua Zhu:** Writing – review & editing, Writing – original draft, Visualization, Supervision, Methodology, Investigation, Data curation, Conceptualization. **Xing Wang:** Writing – review & editing, Writing – original draft, Visualization, Supervision, Project administration, Investigation, Funding acquisition, Formal analysis.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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