Journal of Exercise Science & Fitness 21 (2023) 131–137

Contents lists available at ScienceDirect

Journal of Exercise Science & Fitness

journal homepage: www.elsevier.com/locate/jesf

Effect of Baduanjin exercise on cerebral blood flow and cognitive frailty in the community older adults with cognitive frailty: A randomized controlled trial

Huiying Lin [a, b], Yu Ye [b], Mingyue Wan [b], Pingting Qiu [b], Rui Xia [b], Guohua Zheng [a, *]

[a] College of Nursing and Health Management, Shanghai University of Health & Medicine Sciences, Pudong New District, Shanghai, China
[b] College of Rehabilitation Medicine, Fujian University of Traditional Chinese Medicine, Shangjie University Town, Fuzhou, China

ARTICLE INFO

Article history:
Received 20 September 2022
Received in revised form
26 November 2022
Accepted 1 December 2022
Available online 7 December 2022

Keywords:
Baduanjin
Cerebral blood flow
Cognitive frailty
Mechanisms
Randomized controlled trial

ABSTRACT

Objectives: Regular Baduanjin exercise training has been shown to be beneficial to the physical and cognitive health of older adults, but the underlying mechanisms remain to be investigated. This study examined the influence of Baduanjin on cerebral hemodynamics in community-dwelling older adults with cognitive frailty.
Design: Randomized controlled trial.
Methods: A total of 102 eligible participants were randomly allocated into the Baduanjin exercise intervention group (BEG) or usual physical activity control group (CG) for 24 weeks. Cerebral hemodynamic parameters of bilateral middle/anterior cerebral artery and basilar artery, cognitive ability and physical frailty were assessed using Transcranial Doppler (TCD), Montreal Cognitive Assessment (MoCA) and Edmonton Frailty Scale (EFS) at baseline and 24 weeks post-intervention.
Results: After 24 weeks intervention, the changes in peak systolic velocity (PSV), mean blood flow velocity (MBFV), and end diastolic velocity (EDV) in the right middle cerebral artery and basilar artery were better in the BEG than in the CG; the increase in MoCA scores and the decrease in EFS scores were significantly higher in the BEG than in the CG. Moreover, the interaction of exercise and time on those variables showed obvious significance.
Conclusions: The 24 weeks Baduanjin exercise training had a positive beneficial effect on cerebral blood flow in community-dwelling older adults with cognitive frailty. This may be a potential mechanism by which Baduanjin exercise improves the cognitive frailty in older adults.
Trial registration: Chinese Clinical Trial Registry, ChiCTR1800020341.
Date of registration: December 25, 2018, http://www.chictr.org.cn/showproj.aspx?proj=29846.

1. Introduction

Both cognitive impairment and physical frailty are two important indicators of the aging process [1-3]. While cognitive frailty (CF) was defined as the simultaneous presence of both cognitive impairment and physical frailty in non-demented older adults by the International Academy of Nutrition and Aging and the International Association of Gerontology and Geriatrics in 2013 [4,5], which is associated with adverse health outcomes, including disability, hospitalization and death.[6,7] Studies have demonstrated that there is a bidirectional relationship between physical frailty and cognitive decline; physical frailty is usually a significant risk for cognitive decline and vice versa.[8] It is widely accepted that brain health is closely linked to physical health and cognitive ability. The brain is the most metabolically active organ, and it depends heavily on cerebral blood flow (CBF) to sustain neuronal metabolism.[9]

CBF increases the response to regional neuronal activation to

Abbreviations: ACA, anterior cerebral artery; BA, basilar artery; CBF, cerebral blood flow; CF, cognitive frailty; EDV, end diastolic velocity; EFS, Edmonton frailty scale; GDS, global deterioration scale; ITT, intention-to-treat; MBFV, mean of blood flow velocity; MCA, middle cerebral artery; MoCA, Montreal cognitive assessment; PSV, peak systolic velocity; TCD, transcranial doppler.

* Corresponding author.
E-mail addresses: 408989053@qq.com (H. Lin), 564506234@qq.com (Y. Ye), 783060561@qq.com (M. Wan), 960099726@qq.com (P. Qiu), 251755074@qq.com (R. Xia), zhenggh@sumhs.edu.cn (G. Zheng).

https://doi.org/10.1016/j.jesf.2022.12.001

meet metabolic demands,[10] and impaired cerebral hemodynamics is associated, at least in part, with poor cognitive function and physical frailty.[11–13] Recent studies have reported that those with a frail phenotype have more extensive cerebrovascular damage than non-frail older adults,[11,14] and that cerebral microvascular dysfunction or the hemodynamic impairment is associated with accelerated cognitive decline.[15,16] In almost all forms of cognitive impairment, from mild cognitive impairment to Alzheimer's disease, changes in cerebrovascular function and structure result in reduced cerebral blood flow, which may trigger or exacerbate cognitive impairment.[17] Therefore, hemodynamic changes have important clinical value in predicting future progression of cognitive decline and physical frailty.

Physical activity or exercise intervention that can ameliorate age-related cardiovascular decline may improve the CBF availability, thereby decreasing the risk of cognitive impairment and physical frailty.[18] However, considering the difference on the energetic, metabolic, and the exercise-induced physiological/psychological mechanisms among different exercise types, each type of exercise causes different healthy effects.[19] Different from the conventional aerobic exercise, the mind-body exercise type, such as Yoga and Tai Chi, combined the characteristics of aerobics, meditation, and flexibility. These exercise types focus more on promoting inner peace and mental clarity through slow movements with breathing control. Although each mind-body exercise type is constituted by different postures and movements, and originates from different theoretical bases. For example, yoga is a curious ancient art which combines a set of India religious beliefs with a strange and mysterious practical discipline; while Tai chi belongs to one of Chinese Qigong exercises based on the theory of Chinese traditional medicine.[20] Like Tai chi, Baduanjin exercise also is one of the most widely practiced forms of traditional Chinese mind-body exercise, consisting of eight individual postures and movements with low to mediate exercise intensity; characterized by symmetrical body postures and movements, breathing control, meditative states, and mental concentration.[21] Baduanjin exercise emphasizes the practice of mind-body integration to improved physical, mental, and cognitive health by cultivating *Qi* (a vital energy based on the Traditional Chinese medicine), and is recommended for older adults in China.[22–24] A recent preliminary study found that Baduanjin training has the potential to improve physical and cognitive function and reverse frailty status in pre-frail/frail older adults.[25] Our previous study also found that a supervised 12-week Baduanjin exercise intervention significantly improved some hemodynamic parameters in community-dwelling older adults at risk for ischemic stroke, such as the maximum, minimum or mean blood flow velocities of some entering cerebral arteries,[26] indicating the Baduanjin exercise intervention may effectively modulate cerebral hemodynamics in community-dwelling older adults. Considering that the possible pathologic mechanisms associated with cerebrovascular stenosis leading to insufficient CBF is the same as that of cognitive frailty, it is reasonable that Baduanjin exercise intervention would modulate cerebral blood flow in community-dwelling older adults with cognitive frailty. Therefore, we investigated the effects of Baduanjin exercise on cerebral blood flow, cognitive and physical function in community-dwelling older adults with cognitive frailty.

2. Methods

2.1. Study design

This two-arm randomized controlled trial was conducted in Fuzhou, China. Ethics approval was obtained from the Ethics Committee of the Affiliated Rehabilitation Hospital of Fujian University of Traditional Chinese Medicine (no. 2018-KL015). All study procedures were conducted in accordance with the Declaration of Helsinki 1975. The trial was registered prospective on Chinese Clinical Trial Registry, ref: ChiCTR1800020341.

2.2. Participants recruitment and randomization

The protocol for this study has been published previously.[27] In brief, a total of 120 community older adults with cognitive frailty were recruited between December 2018 and June 2019 through poster advertisement, leaflets, WeChat and Community Service Station at three Community Center of Fuzhou city. Older adults who were interesting in this trial first completed a screening to assess their eligibility according to the following inclusion criteria: aged over 60 years; met the cognitive frailty, including ① Edmonton Frailty Scale (EFS)'s scores$\geq$5 points,[28]②Montreal Cognitive Assessment (MoCA)'s scores<26 points,[29] and no dementia (Global Deterioration Scale (GDS) grade of II or III)[30]; and without regular physical exercise for at least six months (regular physical exercise was defined as any exercise with a frequency of at least twice a week and at least 20 min per session). Those with uncontrolled hypertension (the systolic blood pressure was greater than 160 mmHg or the diastolic blood pressure was greater than 100 mmHg after medication), severe organ failure, cardiovascular disease, musculoskeletal system disorders and other contraindications to exercise, and history of alcohol and drug abuse were excluded. Eligible individuals then had an informed discussion with the trained research assistants. After written the informed consent, participants were arranged the baseline assessment, then were randomly allocated into the Baduanjin exercise training group or the control group. The randomization schedule was prepared and managed by an independent statistician using the PLAN program of statistical software SAS v9.2.

2.3. Intervention

Participants randomly allocated into the control group (CG) received only a health education program on nutrition and diet-related knowledge, which consisted of lectures (30 min per session, once every 8 weeks); Those allocated in the Baduanjin exercise training group (BEG) received both a 24-week Baduanjin exercise training and the same health education program as the control group. The frequency of Baduanjin exercise training was 60 min per day, 3 days per week, consisting of a 15-min warm-up, 40 min of Baduanjin training, and 5 min cool-down. Three professional instructors were employed to guide the participants' practice in Baduanjin exercise.

2.4. Outcome measures

Cerebral blood flow was assessed by cerebral hemodynamic parameters that were measured non-invasively using Transcranial Doppler (TCD) ultrasound by fitting a headpiece supporting an ultrasound probe in each temporal region of the participant (Delica, product type: EMS-9A). Those cerebral hemodynamic parameters included peak systolic velocity (PSV), mean blood flow velocity (MBFV), and end diastolic velocity (EDV) were recorded in the bilateral middle cerebral artery (MCA), bilateral anterior cerebral artery (ACA), and basilar artery (BA).

Cognitive ability was assessed using Beijing Version of the Montreal Cognitive Assessment (MoCA), which is a brief cognitive screening test with good validity and sensitivity in the Chinese population.[29] Physical frailty was assessed using the Chinese version of the Edmonton Frailty Scale (EFS). The EFS scale consists of nine domains such as cognition, basic health, independence, social support, drug use, nutrition, mood, control, and function performance, with a good inter-rater reliability (k = 0.77).[28]

All outcome assessments were measured by blinded assessors at baseline and at the end of the 24-week intervention period.

2.5. Statistical analyses

Baseline characteristics between two groups were presented as mean with standard deviation, median (interquartile) or frequency with percentage, and was compared using independent *t*-test or Mann-Whitney *U* test for continuous variables and Pearson χ^2 or Fisher's exact test for categorical variables, as appropriate. To evaluate preliminary effect of the intervention on outcomes of cognitive frailty and cerebral hemodynamic parameters, we conducted a comparison of mean difference between the two groups from baseline to 24 weeks post-intervention. The linear mixed model with restricted maximum likelihood method was used to analyze the interaction effects of group and time. These analyses followed the principle of intention-to-treat (ITT) analysis in which all randomized participants were included in the data set, and missing data were imputed using the multiple imputation method. All data statistics and analysis were processed in the SPSS V.24.0 software package, and $P < 0.05$ was considered significant.

3. Results

3.1. Baseline characteristics of the study group

From December 2018 to June 2019, a total of 2584 community-dwelling older adults were screened from three Community centers of Fuzhou city in China. Of these, 2482 individuals were excluded because they met certain exclusion criteria (741 individuals), did not meet the inclusion criteria (1677 individuals), or did not wish to participate after discussing the informed consent (64 individuals). So, 102 participants were randomly allocated into the BEG (n = 51) and the CG (n = 51). During the intervention period, six participants in the BEG and five participants in the CG dropped out of the trial due to loss to follow-up, voluntary withdrawal, or unwillingness to complete the second outcome measures. The flow chart of the participant is presented in Fig. 1. Baseline characteristics besides age were homogeneous between the two groups (Table 1).

3.2. Cognitive ability and physical frailty

There were no statistically significant differences in MoCA and EFS scores between the two groups at baseline. After the intervention, the average MoCA scores were increased 2.51 (SD, 0.32) in the BEG, and significantly higher than in the CG (0.34 ± 0.44; $P < 0.001$); whereas the average EFS scores were decreased 1.94 scores (SE, 0.20) in the BEG, significantly lower than in the CG (−1.16 ± 0.23; $P = 0.012$), and there was a significant interaction effect between groups and times ($P < 0.01$ for MoCA and $P = 0.01$ for EFS) (Table 2).

3.3. Cerebral hemodynamic parameters

At baseline, cerebral blood flow between the BEG and the CG was homogeneous regarding PSV, MBFV and EDV in all measured cerebral arteries, except EDV in BA. After the intervention, PSV and MBFV in RMCA, PSV in LMCA, and PSV, MBFV and EDV in BA were significantly different between the two groups (all $P < 0.05$), and there were significant interactions between groups and time for PSV, MBFV and EDV in RMCA, PSV in LMCA, and MBFV and EDV in BA. BEG had increased MBFV in RMCA, and MBFV and EDV in BA, while they were decrease in CG. PSV in RMCA and LMCA and PSV in BA decreased in both BEG and CG, but the decrease was significantly lower in the CG than in the BEG. Comparison between BEG and CG before and after intervention regarding cerebral blood flow is shown in Table 3.

4. Discussion

In this randomized controlled trial, the results showed that the MoCA scores, PSV, MBFV and EDV in the right middle cerebral artery, PSV in the left middle cerebral artery, MBFV and EDV in the basilar artery were significantly higher in Baduanjin group than in the control group after intervention, as well as the EFS scores were significantly lower than in the control group, and there was a significant group and time interaction effect. These results indicate that Baduanjin exercise training for 24 weeks may be beneficial in improving cognitive and physical function, and modulating cerebral blood flow in community-dwelling older adults with cognitive frailty.

The MoCA and EFS scales have been widely applied to screen for cognitive impairment and physical frailty, and to evaluate the effect of cognitive/physical-related interventions in community or clinical older adults.[31,32] The systematic reviews showed a positive association between Baduanjin exercise training and improvement in cognitive and physical function in healthy older adults or older adults with chronic diseases.[22–24] The results in present trial also showed that a 24-week Baduanjin exercise intervention could significantly increase MoCA scores and decrease EFS scores in community-dwelling older adults with cognitive frailty. This suggests that regular Baduanjin training can be effective in improving cognitive frailty in community older adult population. Several physiological mechanisms could explain the beneficial effect of Baduanjin exercise on cognitive and physical function. For example, regular Baduanjin training has been shown to increase resting functional connectivity and grey matter volume in brain regions associated with cognitive or physical function, such as the default mode network, dorsal attention network and insula.[33–36]

The brain is supplied with blood by the internal carotid arteries (ICA) and the vertebral arteries. The ICA gives rise to the anterior cerebral artery (ACA) and the middle cerebral artery (MCA). The two vertebral arteries unite to form the basilar artery and terminate in the two posterior cerebral arteries.[37] Clinical evidence indicates that changes in cerebral vascular function can cause structural remodeling of the brain, leading to impaired function.[38] Cerebral vascular function in human can be assessed by measuring global or regional cerebral perfusion at rest; and the TCD technique may assess changes in cerebral perfusion by measuring blood flow velocity in the large intracranial vessels.[39] Regular aerobic exercise could affect cerebral vascular function in older adults by improving arterial compliance and vascular endothelial function, decreasing oxidative stress and inflammation,[40] and may increase cerebral perfusion in the region by improving cerebral blood flow, thereby affecting cognitive function and age-related physical decline,[9] but its effects depend on numerous factors, such as type, volume, and frequency of exercise performed.

Baduanjin is a traditional Chinese mind-body exercise with the dual characteristics of aerobic exercise and mind-body exercise.[23] In the current study, the BEG increased MBFV and EDV in RMCA and BA after intervention compared to baseline, while those blood velocities were decreased in the CG, and the changes had a statistically significant difference between the two groups. PSV of RMCA, LMCA and BA decreased from baseline to post-intervention in both groups, but the degree of decrease in those blood velocity was significantly higher in the CG than in the BEG. It is known that resting MCA blood velocity (MCAv) decreases with age, and the

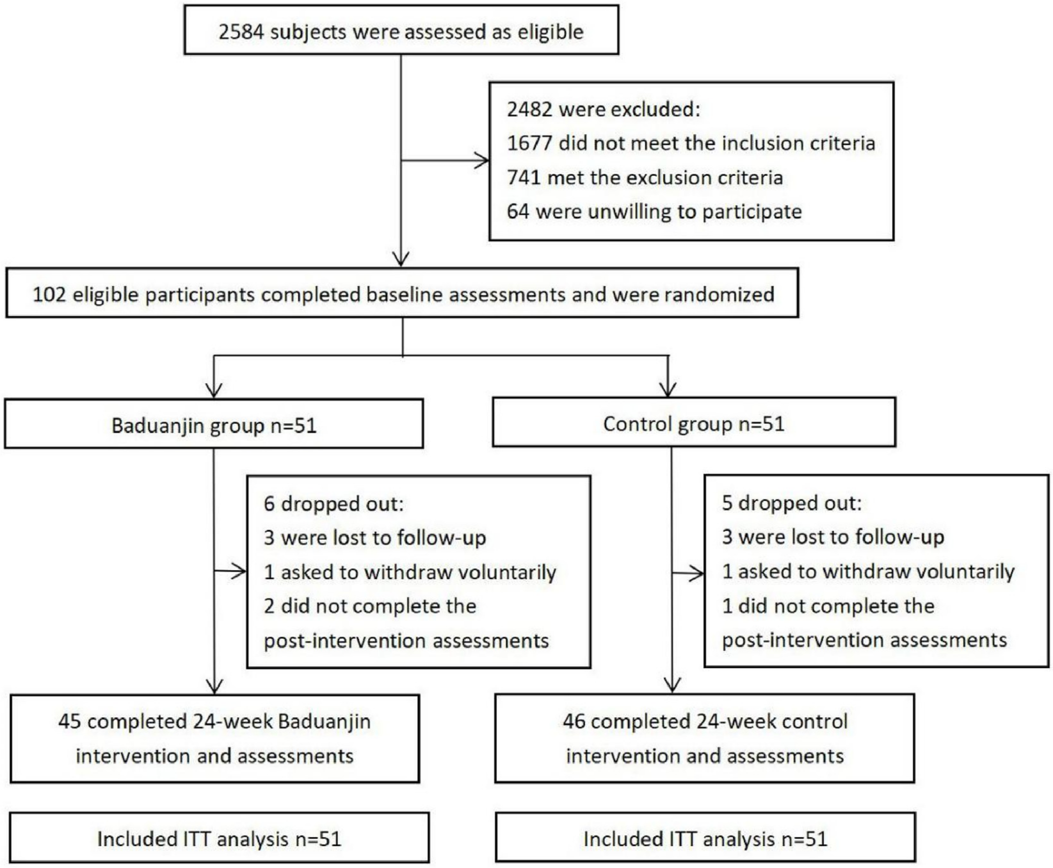

Fig. 1. Participant screening flowchart.

Table 1
Comparison of general demographic information of participants (n/mean ± SD).

Variables	Baduanjin group (n = 51)	Control group(n = 51)	t/Z/χ^2-value	*P*-value
Age, years (mean ± SD)	67.68 ± 5.19	65.35 ± 5.15	−2.305	0.021
Gender (Male/Female) (n)	19/32	20/31	0.042	0.839
Education level (years, mean ± SD)	10.90 ± 2.81	10.02 ± 2.90	−1.539	0.124
BMI (mean ± SD)	23.75 ± 2.33	24.32 ± 3.22	−1.021	0.310
History of hypertension (Without/With) (n)	30/21	31/20	0.041	0.840
History of diabetes (Without/With) (n)	38/13	41/10	0.505	0.477
History of dyslipidemia (Without/With) (n)	37/14	41/10	0.872	0.350
Smoking (Without/With) (n)	48/3	46/5	0.543	0.461
Drinking (often/occasionally/rarely/never) (n)	2/11/7/31	1/10/6/34	0.596	0.897
GDS (II/III) (n)	34/17	36/15	0.182	0.670
EFS scores (mean ± SD)	5.41 ± 0.64	5.67 ± 1.16	0.538	0.591
MoCA scores (mean ± SD)	22.67 ± 2.83	21.55 ± 3.67	−1.348	0.178

Abbreviations: BMI, Body Mass Index; GDS, Global Deterioration Scale; EFS, Edmonton Frailty Scale; MoCA, Montreal Cognitive Assessment.

Table 2
Comparison of the Baduanjin exercise training group and the control group before and after the intervention in relation of MoCA and EFS scores.

Variables	Baseline (mean ± SD)			Mean difference from after intervention to baseline (MD±SE)			P_3
	BEG (n = 51)	CG (n = 51)	P_1	BEG (n = 51)	CG (n = 51)	P_2	
MoCA scores	22.67 ± 2.83	21.55 ± 3.67	0.178	2.51 ± 0.32	0.34 ± 0.44	<0.01	<0.01
EFS scores	5.41 ± 0.64	5.67 ± 1.16	0.591	−1.94 ± 0.20	−1.16 ± 0.23	0.012	0.010

P_1:Comparision of baseline between groups: P_2: Comparison of mean difference after intervention between two groups; P_3: Group × time interaction based on the mixed linear model. MoCA: Montreal Cognitive Assessment; EFS: Edmonton Frailty Scale.

declined MCAv may be a contributor in the pathogenesis of age-related cerebrovascular disease.[41] An increasing number of studies have reported that lower MBFV or PSV in MCAs is associated with risk of cardiovascular disease and cognitive decline.[42–44]

Table 3
Comparison of the Baduanjin exercise training group and the control group before and after the intervention in relation of cerebral blood flow velocity measured by transcranial Doppler (n = 99).

Variables	Baseline (mean (Median, 25%–75%))			Mean difference from after intervention to baseline (MD±SE)			P_3
	BEG (n = 48)	CG (n = 51)	P_1	BEG (n = 48)	CG (n = 51)	P_2	
RMCA _PSV,cm/s	91.5(81–105)	96(84–117)	0.415	−1.31 ± 1.66	−8.48 ± 2.23	0.046	0.012
RMCA _MBFV,cm/s	57.5(48.3–63.8)	60(51–76)	0.175	1.65 ± 1.49	−4.61 ± 1.61	0.029	0.005
RMCA _EDV,cm/s	39(32–45)	42(33–54)	0.106	2.64 ± 1.69	−2.60 ± 1.41	0.138	0.019
LMCA _PSV,cm/s	98(86–116.8)	94(85–111)	0.796	−2.97 ± 2.12	−8.21 ± 1.50	0.022	0.045
LMCA _MBFV,cm/s	61.5(52–70)	60(51–73)	0.54	−1.65 ± 1.19	−3.59 ± 1.16	0.247	0.247
LMCA _EDV,cm/s	41(35.3–47.8)	43(35–54)	0.295	−0.48 ± 0.99	−1.78 ± 1.15	0.395	0.395
RACA_ PSV,cm/s	82(71–92.3)	83(73–91)	0.853	−1.73 ± 2.40	−4.39 ± 1.90	0.636	0.385
RACA_MBFV,cm/s	49(43–56.5)	50(44–59)	0.418	−0.53 ± 1.43	−1.96 ± 1.30	0.570	0.461
RACA_EDV,cm/s	32.5(27–38.8)	35(30–44)	0.144	0.01 ± 1.15	−0.65 ± 1.10	0.680	0.680
LACA_ PSV,cm/s	82(67.8–96.3)	81(71–94)	0.911	−3.46 ± 1.76	−5.93 ± 1.77	0.327	0.327
LACA_MBFV,cm/s	49(42–58.5)	49(43–59)	0.515	−1.61 ± 1.13	−2.72 ± 1.09	0.482	0.482
LACA_EDV,cm/s	34(27–40)	34(29–45)	0.355	−0.22 ± 0.91	−1.35 ± 0.95	0.561	0.396
BA_PSV,cm/s	62.3 ± 19.70	67.1 ± 23.66	0.262	−1.28 ± 1.99	−6.74 ± 2.33	0.024	0.078
BA_ MBFV,cm/s	37.7 ± 10.46	42.3 ± 14.78	0.073	0.22 ± 0.93	−3.78 ± 1.55	0.041	0.029
BA_EDV,cm/s	25.4 ± 6.65	29.9 ± 10.83	0.011	1.05 ± 0.76	−2.53 ± 1.18	0.012	0.012

P_1:Comparision of baseline between groups: P_2: Comparison of mean difference after intervention between two groups; P_3: Group × time interaction based on the mixed linear model. PSV, peak systolic velocity; MBFV, mean blood flow velocity; EDV, end diastolic velocity; RMCA: right middle cerebral artery; LMCA: left middle cerebral artery: RACA: right anterior cerebral artery; LACA: left anterior cerebral artery; BA: basilar artery.

Moreover, Ainslie et al.' study showed the evidence that regular aerobic exercise in healthy men improved MCAv.[45] Another author also reported the association of MCAv with improved cognitive function in aging adults after regular aerobic exercise interventions.[40] As mentioned above, Baduanjin exercise is also aerobic exercise, but has the characteristics of mind-body exercise. Therefore, the findings of this trial should be reasonable. In addition, a recent cross-sectional study also reported long-term Tai Chi training (another traditional Chinese mind-body exercise as Baduanjin exercise) significantly increased the carotid blood flow velocity, including mean blood flow velocity, maximal blood flow velocity and minimum blood flow velocity, in community-dwelling older adults,[46] which also provided support for our findings.

Basilar artery is the main vessel of the posterior circulation that is responsible for most of the brainstem and occipital lobes, as well as parts of the cerebellum and thalami, which are associated with cognitive and related physical functions.[47] With aging, cerebral blood flow to this region decreases, leading to impaired cognitive and physical function. Physical activity or exercise may improve perfusion in those brain regions (e.g., hippocampus and anterior cingulate) causing structural and functional changes that contribute to the cognitive improvement.[48,49] A study reported that moderate exercise could increase the amplitude response of the cerebral artery blood flow velocity, which was associated with improved cardiopulmonary fitness.[50] Our current study showed that the flow velocity of basilar artery was significantly increased in the Baduanjin group compared to the control group, with a significant group and time interaction, which may indicate a positive effect of Baduanjin on cerebral blood flow changes in basilar artery.

Some limitations of this study should be recognized. Firstly, some blood flow parameters in some cerebral arteries were not measured in some participants of both groups due to the lack of a temporal acoustic window for completion of TCD, which may lead to biased results. Though some missing data of them were filled in by using the multiple imputation method. Secondly, due to the specificity of the exercise intervention, participants and coaches cannot be blinded. Thirdly, cerebral blood flow velocity measured by TCD in this study could only indirectly estimate the changes of cerebral blood perfusion.

5. Conclusions

A 24-week regular Baduanjin exercise facilitated cognitive and physical function improvement in community-dwelling older adults with cognitive frailty. Moreover, Baduanjin training had a positive effect on cerebral blood flow, increasing PSV, MBFV and EDV in right middle cerebral artery, PSV in left middle cerebral artery, and MBFV and EDV in basilar artery, suggesting possible mechanisms for improvement of cognitive and physical function. Therefore, the current study may provide useful evidence for the implementation of Baduanjin exercise programs for the treatment of cognitive frailty in the community elderly population. However, large trials are still needed to confirm these results.

Ethics approval and consent to participate

This study was approved by the ethics committee of the Rehabilitation Hospital of Fujian University of Traditional Chinese Medicine (no. 2018-KL015), and in accordance with the World Medical Association and Helsinki Declaration. At the beginning of the study, participant was informed that the study was voluntary and they had the rights to quit at any time. The written informed consent was obtained from all individual participants included in this study. This study had been registered on December 25, 2018 (clinical trial registration number: ChiCTR1800020341).

Consent for publication

Not applicable.

Availability of data and materials

The data supporting the findings of this study are available within the article. The data during the current study are not publicly available due ethical restrictions. The datasets are available upon reasonable request from the corresponding author.

Conflicts of interest

All authors declare that there are no conflicts of interest.

Funding

Funding for this study was provided by National Natural Science Foundation of China (Grant No.82074510). The funder has not input into the study design, protocol preparation, data analysis and interpretation.

Authors' contributions

GHZ developed first conception and design of the trial and obtained funding. HYL, YY, MYW, PTQ and RX developed the design and participated in acquisition and interpretation of data. HYL drafted the manuscript. GHZ revised the manuscript. All authors have approved the submitted version of the manuscript.

Declaration of competing interest

No conflict of interest exits in the submission of this manuscript, and manuscript is approved by all authors for publication.

Acknowledgements

We are grateful to all participants who participated in this study. We also thank all staff of community services for their participation and valuable contribution to this study.

Abbreviations

CF	cognitive frailty
MoCA	Montreal cognitive assessment
EFS	Edmonton frailty scale
GDS	global deterioration scale
CBF	cerebral blood flow
MCA	middle cerebral artery
ACA	anterior cerebral artery
BA	basilar artery
TCD	transcranial doppler
PSV	peak systolic velocity
MBFV	mean of blood flow velocity
EDV	end diastolic velocity
ITT	intention-to-treat

References

1. Clegg A, Young J, Iliffe S, et al. Frailty in elderly people. *Lancet*. 2013;381(9868): 752–762.
2. Lissek V, Suchan B. Preventing dementia? Interventional approaches in mild cognitive impairment. *Neurosci Biobehav Rev*. 2021;122:143–164.
3. McGrattan AM, Zhu Y, Richardson CD, et al. Prevalence and risk of mild cognitive impairment in low and middle-income countries: a systematic review. *J Alzheimers Dis*. 2021;79(2):743–762.
4. Tsutsumimoto K, Doi T, Makizako H, et al. Association of social frailty with both cognitive and physical deficits among older people. *J Am Med Dir Assoc*. 2017;18(7):603–607.
5. Kelaiditi E, Cesari M, Canevelli M, et al. Cognitive frailty: rational and definition from an (I.A.N.A./I.A.G.G.) international consensus group. *J Nutr Health Aging*. 2013;17(9):726–734.
6. Panza F, Lozupone M, Solfrizzi V, et al. Different cognitive frailty models and health- and cognitive-related outcomes in older age: from epidemiology to prevention. *J Alzheimers Dis*. 2018;62(3):993–1012.
7. Chen C, Park J, Wu C, et al. Cognitive frailty in relation to adverse health outcomes independent of multimorbidity: results from the China health and retirement longitudinal study. *Aging*. 2020;12(22):23129–23145.
8. Robertson DA, Savva GM, Kenny RA. Frailty and cognitive impairment–a review of the evidence and causal mechanisms. *Ageing Res Rev*. 2013;12(4):840–851.
9. Tarumi T, Zhang R. Cerebral blood flow in normal aging adults: cardiovascular determinants, clinical implications, and aerobic fitness. *J Neurochem*. 2018;144(5):595–608.
10. Paulson OB, Hasselbalch SG, Rostrup E, et al. Cerebral blood flow response to functional activation. *J Cerebr Blood Flow Metabol : Off J.Int Soc Cereb Blood Flow Metab*. 2010;30(1):2–14.
11. Avila-Funes JA, Pelletier A, Meillon C, et al. Vascular cerebral damage in frail older adults: the AMImage study. *J Gerontol Biol Sci Med Sci*. 2017;72(7): 971–977.
12. Lutski M, Haratz S, Weinstein G, et al. Impaired cerebral hemodynamics and frailty in patients with cardiovascular disease. *J Gerontol Biol Sci Med Sci*. 2018;73(12):1714–1721.
13. Davenport MH, Hogan DB, Eskes GA, et al. Cerebrovascular reserve: the link between fitness and cognitive function? *Exerc Sport Sci Rev*. 2012;40(3): 153–158.
14. Lu WH, de Souto Barreto P, Rolland Y, et al. Cross-sectional and prospective associations between cerebral cortical thickness and frailty in older adults. *Exp Gerontol*. 2020;139, 111018.
15. Balestrini S, Perozzi C, Altamura C, et al. Severe carotid stenosis and impaired cerebral hemodynamics can influence cognitive deterioration. *Neurology*. 2013;80(23):2145–2150.
16. Lazar RM, Marshall RS. Cerebral hemodynamics and cognitive decline: swimming against the current. *Neurology*. 2013;80(23):2086–2087.
17. Fouda AY, Fagan SC, Ergul A. Brain vasculature and cognition. *Arterioscler Thromb Vasc Biol*. 2019;39(4):593–602.
18. Boraxbekk CJ, Salami A, Wåhlin A, et al. Physical activity over a decade modifies age-related decline in perfusion, gray matter volume, and functional connectivity of the posterior default-mode network-A multimodal approach. *Neuroimage*. 2016;131:133–141.
19. Ferreira SA, Stein AM, Stavinski NGL, et al. Different types of physical exercise in brain activity of older adults: a systematic review. *Exp Gerontol*. 2022;159, 111672.
20. Boaventura P, Jaconiano S, Ribeiro F. Yoga and Qigong for health: two sides of the same coin? *Behav Sci*. 2022;12(7).
21. Koh TC. Baduanjin – an ancient Chinese exercise. *Am J Chin Med*. 1982;10(1-4): 14–21.
22. Fang J, Zhang L, Wu F, et al. The safety of Baduanjin exercise: a systematic review. *Evid base Compl Alternat Med*. 2021;2021, 8867098.
23. Zou L, Pan Z, Yeung A, et al. A review study on the beneficial effects of Baduanjin. *J Alternative Compl Med*. 2018;24(4):324–335.
24. Wang X, Wu J, Ye M, et al. Effect of Baduanjin exercise on the cognitive function of middle-aged and older adults: a systematic review and meta-analysis. *Compl Ther Med*. 2021;59, 102727.
25. Liu X, Seah JWT, Pang BWJ, et al. A single-arm feasibility study of community-delivered Baduanjin (Qigong practice of the eight Brocades) training for frail older adults. *Pilot and feasibility studies*. 2020;6:105.
26. Zheng G, Chen B, Fang Q, et al. Baduanjin exercise intervention for community adults at risk of ischamic stroke: a randomized controlled trial. *Sci Rep*. 2019;9(1):1240.
27. Xia R, Wan M, Lin H, et al. Effects of a traditional Chinese mind-body exercise, Baduanjin, on the physical and cognitive functions in the community of older adults with cognitive frailty: study protocol for a randomised controlled trial. *BMJ Open*. 2020;10(4), e034965.
28. Rolfson DB, Majumdar SR, Tsuyuki RT, et al. Validity and reliability of the Edmonton frail scale. *Age Ageing*. 2006;35(5):526–529.
29. Fang Y, Tao Q, Zhou X, et al. Patient and family member factors influencing outcomes of poststroke inpatient rehabilitation. *Arch Phys Med Rehabil*. 2017;98(2):249–255. e242.
30. Reisberg B, Ferris SH, de Leon MJ, et al. Global deterioration scale (GDS). *Psychopharmacol Bull*. 1988;24(4):661–663.
31. Huo Z, Lin J, Bat BKK, et al. Diagnostic accuracy of dementia screening tools in the Chinese population: a systematic review and meta-analysis of 167 diagnostic studies. *Age Ageing*. 2021;50(4):1093–1101.
32. Dent E, Kowal P, Hoogendijk EO. Frailty measurement in research and clinical practice: a review. *Eur J Intern Med*. 2016;31:3–10.
33. Tao J, Liu J, Liu W, et al. Tai chi chuan and Baduanjin increase grey matter volume in older adults: a brain imaging study. *J. Alzheimers. Dis*. 2017;60(2): 389–400.
34. Liu J, Tao J, Liu W, et al. Different modulation effects of Tai Chi Chuan and Baduanjin on resting-state functional connectivity of the default mode network in older adults. *Soc Cognit Affect Neurosci*. 2019;14(2):217–224.
35. Xia R, Qiu P, Lin H, et al. The effect of traditional Chinese mind-body exercise (Baduanjin) and brisk walking on the dorsal attention network in older adults with mild cognitive impairment. *Front Psychol*. 2019;10:2075.
36. Tao J, Chen X, Egorova N, et al. Tai Chi Chuan and Baduanjin practice modulates functional connectivity of the cognitive control network in older adults. *Sci Rep*. 2017;7, 41581.
37. Yu R, Lui F. *Neuroanatomy, Brain Arteries. StatPearls. Treasure Island (FL): StatPearls Publishing Copyright © 2022*. StatPearls Publishing LLC; 2022.
38. de Roos A, van der Grond J, Mitchell G, et al. Magnetic resonance imaging of cardiovascular function and the brain: is dementia a cardiovascular-driven disease? *Circulation*. 2017;135(22):2178–2195.
39. Tymko MM, Ainslie PN, Smith KJ. Evaluating the methods used for measuring cerebral blood flow at rest and during exercise in humans. *Eur J Appl Physiol*. 2018;118(8):1527–1538.
40. Barnes JN, Pearson AG, Corkery AT, et al. Exercise, arterial stiffness, and cerebral vascular function: potential impact on brain health. *J Int Neuropsychol Soc : JINS*. 2021;27(8):761–775.
41. Perdomo SJ, Ward J, Liu Y, et al. Cardiovascular disease risk is associated with middle cerebral artery blood flow velocity in older adults. *Cardiopulm Phys Ther J*. 2020;31(2):38–46.

42. Pase MP, Grima NA, Stough CK, et al. Cardiovascular disease risk and cerebral blood flow velocity. *Stroke*. 2012;43(10):2803–2805.
43. Kaffashian S, Dugravot A, Nabi H, et al. Predictive utility of the Framingham general cardiovascular disease risk profile for cognitive function: evidence from the Whitehall II study. *Eur Heart J*. 2011;32(18):2326–2332.
44. Xiao Z, Ren X, Zhao Q, et al. Relation of middle cerebral artery flow velocity and risk of cognitive decline: a prospective community-based study. *J Clin Neurosci : official journal of the Neurosurgical Society of Australasia*. 2022;97:56–61.
45. Ainslie PN, Cotter JD, George KP, et al. Elevation in cerebral blood flow velocity with aerobic fitness throughout healthy human ageing. *J Physiol*. 2008;586(16): 4005–4010.
46. Li L, Wang J, Guo S, et al. Tai Chi exercise improves age-associated decline in cerebrovascular function: a cross-sectional study. *BMC Geriatr*. 2021;21(1):293.
47. Schonewille WJ, Wijman CA, Michel P, et al. Treatment and outcomes of acute basilar artery occlusion in the Basilar Artery International Cooperation Study (BASICS): a prospective registry study. *Lancet Neurol*. 2009;8(8):724–730.
48. Burdette JH, Laurienti PJ, Espeland MA, et al. Using network science to evaluate exercise-associated brain changes in older adults. *Front Aging Neurosci*. 2010;2: 23.
49. Renke MB, Marcinkowska AB, Kujach S, et al. A systematic review of the impact of physical exercise-induced increased resting cerebral blood flow on cognitive functions. *Front Aging Neurosci*. 2022;14, 803332.
50. Witte E, Liu Y, Ward JL, et al. Exercise intensity and middle cerebral artery dynamics in humans. *Respir Physiol Neurobiol*. 2019;262:32–39.