AnnalsofClinicalandMedical Case Reports

ResearchArticle

ISSN2639-8109|Volume9

Differential Effects of Long-TermTai Chi Practice on Brain Networks inYoungAdults:A Resting-State Fmri Study

Qinghua Ren, Naying Jin,Yao Sun, Diyang Lyu, Cuiran Du, Ling Zhao, Kuangshi Li, Zongheng Li andYong Zhang[*]Department of Rehabilitation, Dongzhimen Hospital, the first affiliated Hospital of Beijing University of Chinese Medicine, Beijing, 100700, China

[*]**Correspondingauthor:**

YongZhang.
DepartmentofRehabilitation,DongzhimenHospital,
thefirstaffiliatedHospitalofBeijingUniversity
ofChineseMedicine,No.5,Haiyuncang,Dongcheng
District, Beijing, 100700, China,
E-mail: zhangyong_tcm@163.com

Received: 01 May 2022
Accepted: 23 May 2022
Published:27May2022
JShort Name:ACMCR

Citation:

YongZhang,DifferentialEffectsofLong-TermTaiChi Practice on Brain Networks in Young Adults: A Resting-StateFmriStudy.AnnClinMedCaseRep.2022; V9(4):1-6

Keywords:

Tai Chi; Functional magnetic resonance imaging; Defaultmodenetwork;Brainnetworks;Youngadults

1. Abstract

Objective

Tai Chi has been found to modulate the intrinsic brain functions andstructures,whichhasprovidedcluestorevealthemechanisms behind the clinical effects. The aim of the current study was to investigate the influence of long-term Tai Chi practice in young adults.

Methods

Atotal of 27 young adults with long-termTai Chi experience and another 27 age and gender matched healthy control subjects were included in the current study.All the participants underwent trail makingtestsandbrainstructuralandresting-statefunctionalmagnetic resonance imaging assessments.

Results

The demographic information and trail making tests showed no significantdifferences.fMRIresultsshoweddecreasedfunctional connectivity in the left dorsolateral superior frontal gyrus in the Tai Chi group when comparing the changes of the default mode network with the control group. No increased changes in the default mode network and no significant differences in other brain networks were observed.

Conclusions

The current findings suggested decreased differential effects of long-termTaiChipracticeonbrainnetworksinyoungadults.The decreasedresults provided more understanding of the modulation effects as functional plasticity and functional specialization of brainnetworksinyoungadultswithlong-termTaiChiexperience.

2. Introduction

TaiChi,alsocalledTaiChiChuanorTaiji,isafamousintangible cultural heritage that has been practised as a martial art in China forcenturies.Regardedasamind-bodyexercise,TaiChicombines physical movement and meditation to improve motor coordination, postural control, and cognitive function [1-3]. In the past decades, the favorable health values of Tai Chi on both physical and psychological conditions have been highly recognized with a substantial number of previous researches and reviews [4-6].AlthoughtheclinicalbenefitsofTaiChihavebeenwelldocumented, the underlying mechanisms interpreting the observed effects re- main largely unknown in this field [7].

In the past decades, advances in functional magnetic resonance imaging(fMRI)techniqueshaveopenedanewwindowofhuman brain, offering new opportunities to investigate the neurological effects of different interventions [8]. As a special mind-body intervention,Tai Chi has been found to modulate the intrinsic brain functions and structures, which has provided clues to reveal the mechanisms behind the clinical effects of Tai Chi. It has been found that long-term Tai Chi practice could induce decreased fractional amplitude of low frequency fluctuations of the default modenetwork(DMN),thefrontoparietalnetwork,andthedorsal prefrontal-angular gyri network [9].Apart from that, previous studyalsorevealeddecreasedresting-statefunctionalconnectivity between the dorsolateral prefrontal cortex and the middle frontal gyrus [10], but increased gray matter volume in the thalamus and the hippocampus in elder long-term Tai Chi practitioners [11]. In a recent cross-section study, differences in the DMN, the sensory-motor network (SMN), and the visual network (VN) were observed in older women with long-term Tai Chi experience [12].

Given that long-term Tai Chi practice could induce different changes of brain networks in older adults, the aim of the current study was to investigate the influence of long-term Tai Chi practice in young adults, which may enlarge our understanding of the effects of Tai Chi on different populations. It was hypothesized that long-termTai Chi practice could induce different changes on resting-state brain networks in young adults.

3. MaterialsandMethods

Subjects

ThecurrentstudywasapprovedbytheEthicalCommitteeofDongzhimen Hospital, the first affiliated hospital of Beijing University ofChineseMedicine.Writteninformedconsentwasobtainedfrom allparticipantsaccordingtotheDeclarationofHelsinki.Atotalof 27youngadultswithlong-termTaiChiexperienceandanother27 age and gender matched healthy control subjects were includedin the current study. The inclusion criteria of the Tai Chi group were as follows: aged from 18 to 35 years old; right-handed; reg- ularTai Chi experience for more than 1 year; with a frequency of Tai Chi practice for more than 3 times per week and more than30 minutes each time. The inclusion criteria of the control group were as follows: age and gender matched with theTai Chi group; right-handed; with regular physical exercise (walking, jogging, stretching,etal);withoutpreviousexperienceofTaiChi.Theexclusion criteria of both groups were: history of balance or motor function abnormality; history of cerebral, mental, or psychological diseases; history of chronic pain problems; history of alcohol or drug dependency; history of sleep deprivation in the past three months;anyotherhealthproblemsorpoorphysicalconditionsthat may influence the participation; females with plans of pregnancy in one year; participated in other researches during the past three months; any MRI contraindications.

TrailMakingTest

All participants were asked to complete the Trail Making Test (TMT), a neuropsychological instrument that contains two task components, TMT-A and TMT-B, which is extensively used for theassessmentofset-switchingabilityacrossawiderangeofneurological conditions [13].

ImagingAcquisition

Inordertoobtainhighqualityimagingdata,wesetupthefollowing rules for quality control during imaging acquisition.All scanningshouldbearrangedthreedaysinadvance.Menstrualperiods should be avoided for female participants. All participants were told to maintain regular daily life and plenty of sleep prior to the scanning.All participants should stay rest for at least 20 minutes beforescanning.Allscanningshouldbearrangedatleastonehour away from meals.All scanning were operated by the same qualifieddoctor.Participantswereinstructedtostaystill,thinkofnothinginparticular,keepeyesclosed,andnottofallasleepduringthe scanning.Earplugswereworntoattenuatescannernoiseandfoam head holders were immobilized to minimize head movements during each scanning.

Functional magnetic resonance images were acquired with a 3.0 Tesla MRI scanner (Siemens, Sonata Germany) at Dongzhimen Hospital,Beijing,China.Forthefunctionalscanning,resting-state fMRI data was collected using a single-shot, gradient-recalled echo-planarimagingsequencewiththefollowingparameters:repetition time = 2000 ms, echo time = 30 ms, flip angle = 90°, matrix = 64×64, field of view = 240mm2, slice thickness = 3.5 mm, gap = 1 mm, 32 interleaved axial slices, and 180 volumes. The high-resolution structural information for anatomical localization wasacquiredusing3DMRIsequenceswiththefollowingparameters:voxelsize=1mm3,repetitiontime=2530ms,echotime = 3.4 ms, flip angle = 12°, matrix = 512×512, field of view = 240 mm×240 mm, slice thickness = 1 mm.

DataprocessingandAnalysis

Thestructuraldataandthefunctionaldatawerepreprocessedseparatelytoapproachsurface-basedanalysis.Theresting-statefunctionaldataprocessingandanalyzingweremainlycarriedoutwith the statistical parametric mapping toolbox (SPM12) andAnalysis of Functional NeuroImages (AFNI). The structural data processingwasmainlycarriedoutwithFreeSurfersoftware(https://surfer.nmr.mgh.harvard.edu/). Compared to the volume-based analysis, surface-basedanalysismayperformbetterinincreasingstatistical power.Duetothecomplexstructureofourbrain,someareasmay be neighboring in volume-domain, but far away from each other in anatomy and play absolutely different roles in brain functional networks. Volume-based analysis is unable to avoid this kind of potential bias, while surface-based analysis can minimize the influence of other signals on gray matter signals and provide more reliable results.

A total of 170 volumes for each subject were corrected for slice timing after the starting 10 volumes were discarded for signal equilibrium.After that, the slice-timing was performed to correct acquisition time delay among different slices for remaining 170 volumestotheacquisitionofthesliceacquiredinthemiddletime of each time repetition (TR). The slices of each participant were realignedby registeringtothefirst imageandthentothe meanof the volume. None of the participants were excluded from further analysis due to excessive head motion (> 3mm or 3°). Then, we performedtemporalbandpassfiltering(0.01-0.1Hz)foreachparticipant’stimeseriesafterdetrendingthedatatoreducepossible scanner influences.

Corticalsegmentationandreconstructionwereperformedwiththe FreeSurfer image analysis suite. One assessor who was blind to participant characteristics followed the reconstruction procedures to check and correct any mistakes made by the FreeSurfer. We applied the AFNI Surface Mapper (SUMA) program to align reconstructed structural and functional data to the same template space. The functional data was smoothed with a full width half maximum of 8 mm. The brain networks of each participant were identifiedbyusingindependentcomponentanalysis(ICA).Functional data were analyzed with the group ICA of fMRI toolbox. The procedures included the following steps: (i) applyed ICAwith Infomax algorithm as it is very suit for our spatial analysis, and (ii) back reconstructed into individual-level components. Finally, 30 independent components were auto-estimated through analysis. Group mean ICA maps were compared with published ICA templates identified via visual inspection. Following ICA, a back-reconstructed subject-specific time series for the networks were correlated with voxels' time series in a functional connectivityanalysisbyusingthegenerallinearmodel.Themeantime course for each functional network was calculated by averaging the time courses of all voxels within each network mask obtained from ICA analysis.

Forthebetween-groupcomparison,weperformed2-samplet-test toidentifysignificantdifferences.Bothfalsediscoveryrate(FDR) and Monte Carlo Simulations correction were applied to do the multiplecomparisoncorrection(P<0.05).WeusedRESTtoolbox toreportthebrainregionwithsignificantdifference,andtheresult was displayed by using BrainVoyager QX software.

4. Results

DemographicData andBehavioral Results

A total of 54 participants took part in the current study, including27long-term TaiChipractitioners(age:23.74±2.92years, 19 males and 8 females) and another 27 age and gender matched healthysubjects.ThedemographicinformationoftheTaiChiand control groups are shown in Table 1. There were no differences between the two groups in age, gender, body weight, height and educational level.The results of the trail making test also showed no significant differences (see Table 2).

Table1:demographicinformationoftheTaiChiandcontrolgroups.

Items	TaiChigroup(n=27)	Control Group (n=27)	*P*
Age (year)	23.74±2.92	23.74±2.92	NA
Gender (Male/Female)	19/8	19/8	NA
Height (cm)	171.56±8.58	172.07±6.47	0.80
Weight(kg)	64.70±13.59	66.04±12.73	0.71
educational background (year)	16.70±3.00	17.19±2.29	0.51

Table2:resultsofthetrailmakingtests.

Items	TaiChigroup(n=27)	Control Group (n=27)	*P*
trailmaking testA(second)	19.21±5.40	19.08±6.79	0.94
trail making test B (second)	44.05±14.50	43.66±16.81	0.93

fMRIResults

WecomparedtherestingstatefunctionalconnectivityoftheDMN, SMN,andVNbetweentheTaiChiandcontrolgroups.Theresults showed decreased functional connectivity in the left dorsolateral superiorfrontalgyrusintheTaiChigroupwhencomparingthe differencesoftheDMNwiththecontrolgroup.Thespecificcluster locations are shown inTable 3 and Figure 1. No brain regions withincreasedfunctionalconnectivityweredetectedintheTaiChi group compared with the control group. No significant changes were observed in the SMN and VN between two groups.

Table3:decreasedfunctionalconnectivityintheTaiChigroup.

Region	Hem/BA	Talairach			t value	Area	Voxels
		X	Y	Z			
dorsolateral superior frontal gyrus	L/21 48	16	16	55	3.3451	15.5328	21

Note: Results from two-sample t-test, $p < 0.05$, corrected by Monte Carlo Simulations, iterated 1000 times, and cluster size > 80 mm^3.

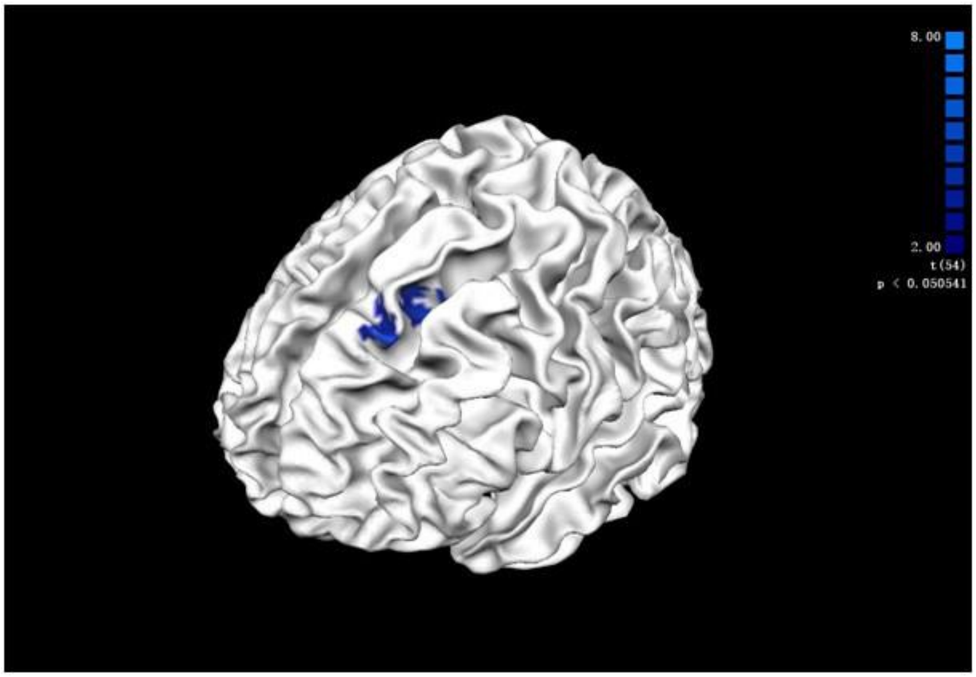

Figure 1: Decreased functional connectivity in the left dorsolateral superior frontal gyrus in the Tai Chi group when comparing the differences of the DMN with the control group. Results from two-sample t-test, $p < 0.05$, corrected by Monte Carlo Simulations, iterated 1000 times, and cluster size > 80 mm3.

5. Discussion

In this study we applied a cross-sectional design to investigate the effects of long-term Tai Chi practice on resting-state brain networks in young adults. We hypothesized that there might be a series of brain regions revealing increased or decreased functional connectivity among different brain networks, such as the DMN, SMN and VN. However, we only detected decreased functional connectivity in the left dorsolateral superior frontal gyrus in the Tai Chi group when comparing the changes of the DMN with the control group. No increased changes in the DMN and no significant differences in other brain networks were observed in our study. There were slight differences between the results of our study and previous studies focusing on the effects of long-term Tai Chi practice. We speculated that our results might provide further interpretations of the functional effects of long-term Tai Chi practice among different populations. It has been widely confirmed by previous fMRI studies that long-term Tai Chi practice can induce increased functional changes in older adults. The cross-section study conducted by Wei and her colleagues revealed significantly thicker cortex in a series of different brain regions of both hemispheres [14] and significantly greater functional homogeneity in the right post-central gyrus [15], which provided evidence for the functional plasticity and functional organization of the brain in long-term Tai Chi practitioners. Other cross-section studies detected larger gray matter volume [11] and similar improvements of white matter [16] in long-term Tai Chi practitioners, which suggested the protective effects of Tai Chi exercise at slowing gray and white matter atrophy in older adults. In another cross-section study, Yue and his colleagues tried to compare the functional effects of long-term Tai Chi practice with walking in older women. There results revealed significant increases of resting-state connectivity in the DMN, SMN and VN [12], as well as white and gray matter density and related network improvements including the hippocampus in the Tai Chi group [17, 18], which were in consist with the above mentioned study supporting the protective effects of Tai Chi in memory performance. In a cohort study, older adults received a six-week intervention that consisted of Tai Chi exercise, cognitive training, and group counseling, while the control group attended health knowledge lectures. The results showed increased resting-state connectivity between the medial prefrontal cortex and medial temporal lobe [19], and reorganized regional homogeneity of spontaneous fluctuations in the blood oxygen level-dependent signals in the superior and middle temporal gyrus and the cerebellum [20], as well as enhanced amplitude of low frequency fluctuations in the middle frontal gyrus, the superior frontal gyrus, and the anterior cerebellum lobe [21]. Taken together, the authors concluded that multimodal Tai Chi intervention can postpone the effects of aging by reorganizing the functions of brain regions affected by aging. Another cohort-study conducted by Tao and her colleagues compared the neural functional effects of 12-week Tai Chi and Baduanjin exercise with normal control. By applying different fMRI data analyzing techniques, this study revealed a series of evidences, such as increased hippocampus-medial prefrontal cortex resting-state functional connectivity [22], increased DMN resting-state connectivity in the medial prefrontal cortex [23], increased grey matter volume [24], and increased low-frequency fluctuations in the frontal lobe [25], which supported the potential effects of Tai Chi practice in preventing memory decline during aging. The differential effects of long-termTai Chi practice on brain networks in older adults have beenwellinvestigatedbytheabovementionedstudies.Therewere converging evidences suggesting that long-term Tai Chi practice caninduceincreasedfunctionalchangesinolderadults.However, to the best of our knowledge, the potential effects of long-term Tai Chi practice on brain networks in young adults have not been well elucidated. In order to enlarge our understanding of the effectsofTaiChiondifferentpopulations,weconductedthecurrent cross-sectionstudywithparticipantsagedfrom18to35yearsold. Inthebeginning,wehypothesizedthatlong-termTaiChipractice couldinducesimilarchangesinyoungadultswiththatoftheolder adults. However, we only detected slightly decreased functional connectivity in the left dorsolateral superior frontal gyrus of the DMNinyoungadults,whichweredifferentfromthesignificantly increased changes in older adults.

There are two possible explanations for the current decreased results. Firstly, our results have provided counterevidence supporting the theory that the brain functional networks, especially the cognition and memory functions, are declining during agingin older adults. That’s the reason why previous studies detected comprehensivelyincreasedchangesinolderadults.Whenitcomes to the young adults, whose brain functions are maintaining in the maturationperiod,thefunctionaleffectsoflong-termTaiChipracticemightbedifferentfromthatoftheolderadults.Secondly,decreased functional changes also have been detected in previous studies investigating the effects of long-term Tai Chi practice in olderadults.Ithasbeenreportedinapreviouscross-sectionstudy that long-term Tai Chi practice in older adults induced decreased functionalhomogeneityintherightdorsallateralprefrontalcortex andtheleftanteriorcingulatecortex[15],anddecreasedfractional amplitude of low frequency fluctuations in the bilateral frontoparietal network, the DMN, and the dorsal prefrontal-angular gyrus network [9].Apart from that, older adults with long-term Tai Chi experiencealsorevealeddecreasedmiddlefrontalgyrusvoxel-mirroredhomotopicconnectivity[26].Inanothercross-section study,decreasedresting-statefunctionalconnectivitybetweenthe dorsolateral prefrontal cortex and the middle frontal gyrus were foundinolderadultswithlong-termTaiChiexperience[10].The cohort-study conducted by Tao and her colleagues detected similar decreases in resting-state functional connectivity between the dorsolateral prefrontal cortex and the left superior frontal gyrus [27]. Researchers of these studies proposed explanations of the decreasedresultsasfunctionalplasticityandfunctionalspecialization of brain networks which might be associated with higher-ordercognitiveabilityinagingpopulation.Thedorsolateralsuperior frontal gyrus, which showed decreased functional connectivity in youngadultswithlong-termTaiChiexperienceinourstudy,coincideswiththeresultsofpreviousstudiesfocusingonolderadults. As a key region of the DMN, the superior frontal gyrus plays an importantroleintheregulationofhumancognition,memory,and behavior. Taken together, our findings might highlight more implicationsfortheunderstandingofthemodulationeffectsoflong-termTaiChipracticeonbrainnetworksinyoungadultsaswellas theolderpopulation.Onelimitationofthecurrentstudyisthatthe interpretation should be taken with cautious because of the small sample size and poor Tai Chi homogeneity. And more behavior measurements are still in need to further determine relationships between functional effects and behavior changes.

6. Conclusions

Inconclusion,ourfindingssuggesteddecreaseddifferentialeffects of long-term Tai Chi practice on brain networks in young adults. Thedecreasedresultsprovidedmoreunderstandingofthemodulationeffectsasfunctionalplasticityandfunctionalspecializationof brainnetworksinyoungadultswithlong-termTaiChiexperience.

7. Funding

ThisworkwasfundedbytheNationalNaturalScienceFoundation of China (No. 81804160, 82004437), the Beijing Natural Science Foundation Project (No. 7204277, 7174318).

References

1. ParcoMS,AngusPY,EdwinCC.EffectsofTaiChiorConvention-al Exercise on Central Obesity in Middle-Aged and Older Adults.Annals of Internal Medicine. 2021; 174: 1050-1057.
2. LyuD,WangJ,YangF.EffectofTaiChionpost-strokenon-motordisorders:asystematicreviewandmeta-analysisofrandomizedcon-trolled trials. Clinical Rehabilitation. 2021; 35: 26-38.
3. WangCC,LiK,ChoudhuryA.TrendsinYoga,TaiChi,andQigongUseAmongUSAdults,2002-2017.AmJPublicHealth.2019;109:755-761.
4. Wang C, Schmid CH, Rones R.Arandomized trial of tai chi for fibromyalgia. N Engl J Med. 2010; 363: 743-754.
5. LyuD,LyuX,ZhangY.TaiChiforStrokeRehabilitation:ASystem-atic Review and Meta-Analysis of Randomized Controlled Trials.Front Physiol. 2018; 9: 983.
6. Zhou Y, Zhao ZH, Fan XH. Different Training Durations and FrequenciesofTaiChiforBoneMineralDensityImprovement:ASystematicReviewandMeta-Analysis.EvidBasedComplementAlter-nat Med. 2021; 2021: 6665642.
7. HuangJ,WangDandWangJ.ClinicalEvidenceofTaiChiExercisePrescriptions:ASystematicReview.Evidence-basedComplementa-ry and Alternative Medicine. 2021; 2021: 5558805.
8. Mao Y, Liao Z, Liu X. Disrupted balance of long and short-rangefunctional connectivity density in Alzheimer’s disease (AD) andmild cognitive impairment (MCI) patients: a resting-state fMRIstudy. Ann Transl Med. 2021; 9: 65.
9. WeiGX,GongZQ,Yang Z.Mind-BodyPracticeChangesFractionalAmplitude of Low Frequency

Fluctuations in Intrinsic Control Net-

works. Front Psychol. 2017; 8: 1049.

10. Liu Z, Wu Y, Li L. Functional Connectivity Within the ExecutiveControl Network Mediates the Effects of Long-Term Tai Chi Exer-cise on Elders’ Emotion Regulation. Front Aging Neurosci. 2018;10: 315.
11. Liu S, Li L, Liu Z. Long-Term Tai Chi Experience Promotes Emotional Stability and Slows Gray Matter Atrophy for Elders. FrontPsychol. 2019; 10: 91.
12. YueC,ZhangY,JianM.DifferentialEffectsofTaiChiChuan(Mo-tor-Cognitive Training) and Walking on Brain Networks: A Rest-ing-State fMRI Study in ChineseWomenAged 60. Healthcare (Ba-sel). 2020; 8: 67.
13. VarjacicA,MantiniD,DemeyereN.NeuralsignaturesofTrailMakingTest performance: Evidence from lesion-mapping and neuroimaging studies. Neuropsychologia. 2018; 115: 78-87.
14. WeiGX,XuT,FanFM.CanTaichireshapethebrain?Abrainmorphometry study. PLoS One. 2013; 8: e61038.
15. WeiGX,DongHM,YangZ.TaiChiChuanoptimizesthefunctionalorganizationoftheintrinsichumanbrainarchitectureinolderadults.Front Aging Neurosci. 2014; 6: 74.
16. Yao J, Song Q, Zhang K. The effect of Tai Chi practice on brainwhite matter structure: a diffusion tensor magnetic resonance imag-ing study. Res Sports Med. 2019; 27: 121-130.
17. YueC,YuQ,ZhangY.RegularTaiChiPracticeIsAssociatedWithImproved Memory as Well as Structural and FunctionalAlterationsoftheHippocampusintheElderly.FrontAgingNeurosci.2020;12:586770.
18. Yue C, Zou L, Mei J.Tai ChiTraining Evokes Significant ChangesinBrainWhiteMatterNetworkinOlderWomen.Healthcare(Basel).2020; 8: 57.
19. LiR,ZhuX,YinS.Multimodalinterventioninolderadultsimprovesresting-state functional connectivity between the medial prefrontalcortexandmedialtemporallobe.FrontAgingNeurosci.2014; 6:39.
20. ZhengZ,ZhuX,YinS.Combinedcognitive-psychological-physicalintervention induces reorganization of intrinsic functional brain ar-chitecture in older adults. Neural Plast. 2015; 713104.
21. Yin S, Zhu X, Li R. Intervention-induced enhancement in intrinsicbrain activity in healthy older adults. Sci Rep. 2014; 4: 7309.
22. TaoJ,LiuJ,EgorovaN.IncreasedHippocampus-MedialPrefrontalCortexResting-StateFunctionalConnectivityandMemoryFunctionafterTaiChiChuan PracticeinElderAdults.FrontAgingNeurosci.2016; 8: 25.
23. Liu J,Tao J, LiuW. Different modulation effects ofTai Chi ChuanandBaduanjinonresting-statefunctionalconnectivityofthedefaultmode network in older adults. Soc CognAffect Neurosci. 2019; 14:217-224.
24. Tao J, Liu J, Liu W. Tai Chi Chuan and Baduanjin Increase GreyMatter Volume in Older Adults: A Brain Imaging Study. J Alzhei-mers Dis. 2017; 60: 389-400.
25. Tao J, Chen X, Liu J. Tai Chi Chuan and Baduanjin Mind-BodyTrainingChangesResting-StateLow-FrequencyFluctuationsintheFrontal Lobe of Older Adults: A Resting-State fMRI Study. FrontHum Neurosci. 2017; 11: 514.
26. Chen LZ,Yuan X, ZhangY. Brain Functional Specialization Is EnhancedAmong Tai Chi Chuan Practitioners.Arch Phys Med Rehabil. 2020; 101: 1176-1182.
27. Tao J, Chen X, Egorova N. Tai Chi Chuan and Baduanjin practicemodulates functional connectivity of the cognitive control networkin older adults. Sci Rep. 2017; 7: 41581.