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fMRI Study of Pain Reaction in the Brain under State of "Qigong"

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Abstract: In this study, 4 male Qigong masters (aged 60 ± 12) who had Qigong practicing experience for more than 30 years were tested. By using the technique of fMRI, the change of brain function under the state of Qigong was observed through the peripheral pain stimulation generated by potassium penetrating method. The fMRI examination was running on a GE signa VH/3.0 T MRI machine and block design was used. The test was repeated several times, which was carried out before and 15 min after Qigong practicing. The heart and respiration rate of these 4 Qigong masters were monitored during the whole test. SPM2 was used for the data analysis, and the result showed that before Qigong practicing, besides SI and SII-insula regions, many other Brodmann areas, the cigulate cortex, the thalamus, and the cerebellum were all activated, while 15 min after that, the activated areas were decreased obviously, which were mainly at the SII-insula region and some other Brodmann areas. Since the SII-insula region was activated in both of these two states, further analysis of the response curve was focused on it. Its response amplitude under the state of Qigong (3.5%) was greater than that before Qigong (1.2%). Our result indicated that the main manifestation of brain functional change under Qigong was functional suppressing, but in some particular regions such as SII-insula region in our study, the response amplitude was increased. Further study of the exact physiological mechanism of Qigong is needed.

Keywords: Qigong; Peripheral Pain Stimulation; Brain Function; fMRI.

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Introduction

Qigong has been a traditional Chinese exercise, which has played a significant role in healthcare and illness recovery through thousands of years in China. The mechanism of Qigong and Qigong-induced effects are still unclear.

Based on the observation that when a master is under the state of Qigong, he is so highly mentally concentrated and will not be interfered by any disturbance, even by a very loud noise or a painful stimulation. We used the peripheral pain stimulation as an intermedium to study the brain function changes.

BOLD fMRI was a powerful neuroimaging technique for its high spatial temporal resolution. In our research, it was used to study the changes of activation in the brain functional areas under or not under Qigong status.

Materials and Methods

Subjects

Four male Qigong masters without any known neurological disorder were included in our study. They aged 45–72 years (60 ± 12), and had the Qigong practicing experience of more than 30 years.

To ensure the achievement of the Qigong state, EEG in each of Qigong masters was performed 1 day before fMRI and recorded continuously from 10 min before to 15 min after beginning Qigong practice. Upon achieving the Qigong state, EEG showed an increase of Alfa band waves in pre-frontal brain area, a decline of dominant frequency, and an increase of coherence index in all 4 Qigong masters. Thus, all 4 masters were enrolled in fMRI imaging of the present study.

Informed consent was obtained and all procedures were approved by the local research ethic committee.

Stimuli

The pain stimulation, which was generated by potassium penetrating method using an algesimeter (WQ-9E, Haidian Electronic and Medical Instrument Factory, Beijing, China), was applied to the middle section of the subject's right leg with the intensity of one's pain threshold.

Procedure

The design of each test followed a 30 sec periodic "on-off" design with pain stimulation in the on phase and no pain in the off phase. The test was repeated twice which was before and 15 min after Qigong practice. When study finished, the subject was asked to report how he felt about the pain during the whole procedure.

fMRI Image Acquisition

Gradient-echo echoplanar magnetic resonance images were acquired using a 3T GE Signa System (GE Signa VH/i 3.0T). An 8 channels head coil was used for radio frequency transmission and reception. In each of 25 contiguous planes parallel to the inter-commissural (AC-PC) plane, 62 $T2^*$-weighted images depicting BOLD contrast were acquired with excitation time (TE) = 35 ms, repeat time (TR) = 3000 ms, flip = 90, in-plane resolution = 3.75 mm, slice thickness = 5 mm. Head movement was limited by foam padding within the head coil. At the same session, a high resolution fast spoil gradient recovery image was acquired in the AC-PC plane with TE = 1.3 ms, TR = 5.4 ms, flip = 15, in-plane resolution = 0.09375 mm, slice thickness = 1.2 mm.

Other Physical Index Monitoring

During the whole image acquisition procedure, the physical index, including the heart rate (HR) and the respiration rate (RR) were monitored using the scanner's built-in photoplethysmograph and respiratory belt. The photoplethysmograph sensor was placed on the subject's right index finger, and the belt was positioned around the abdomen. The cardiac trigger and respiration data were recorded from the scanner's analog gating outputs.

Image Analysis

Images acquired from 4 masters' fMRI scans were analyzed as a group using the General Linear Model (GLM, Statistical Parametric Mapping [SPM2], http://www.fil.ion.ucl.ac.uk) with fix effects analysis. Images were preprocessed for the analysis by realigning the images to correct head motion, and then co-registered to the high resolution anatomical T1-weighted images. Subsequently, the co-registered functional and anatomical images were all spatial normalized to a MRI template in the Montreal Neurological Institute (MNI) space. The normalized functional images were smoothed with a Gaussian kernel of 7 mm, 7 mm, and 10 mm in x, y, and z axes in full width at half-maximum (FWHM). Parametric maps were generated by convolving a box-car function that was matched with stimulus cycle with a hemodynamic response function. The difference of the estimated parameter of the pain and no pain design matrix were analyzed with t-test. Areas that were considered significantly activated if the probability for the cluster, corrected for FDR, was < 0.01.

After the functional activation maps were generated for the pain reaction under or not under Qigong state. A further ROI analysis was focused on the SII-insula region, the response amplitude was obtained from the calculation of the percent BOLD signal change of the pain stimulation during the Qigong or no Qigong state.

Results

Physical Indexes

No heart rate change was found between non Qigong state and the Qigong state, and the mean HR was 65/min. A decrease of the RR from 20/min at non-Qigong state dropped to 6/min at Qigong state, was recorded in 2 masters. In the remaining 2 masters, a mean RR of 22/min at the non-Qigong state did not change after the Qigong state began. The uniformity of the respiration rhythm of 4 masters was all improved in Qigong state.

Subjective Feeling of the Pain

After the study finished, all the masters reported that less pain was felt when he was entering Qigong state than that before Qigong practicing.

Pain Reaction of the Brain

Before Qigong practicing, many brain functional regions were activated mainly at the SI and SII-insula regions when the pain was "on". Besides that many other Brodmann areas, the cigulate cortex, the thalamus, and the cerebellum were all activated (Table 1, Fig.1).

Fifteen minutes after Qigong practicing, the activated areas were obviously decreased, which were mainly at the SII-insula region and some other Brodmann areas, and the cigulate cortex and the thalamus were not activated (Table 2, Fig. 2).

Since the SII-insula region was activated in both Qigong and non-Qigong state, further analysis of the response curve was focused on it. The response amplitude of this region under the state of Qigong (3.5%) was greater than that before Qigong (1.2%, Fig. 3).

Discussion

To date, it is widely accepted that Qigong is effective as a complementary treatment for many diseases. Most researches using evoked potentials and electroencephalography (EEG) proved that the human brain under the Qigong state is in a special condition that is different from ordinary wakefulness, relaxation at rest, and sleeping state (Qin and Qu, 1962; Hong *et al.*, 1998; Cui and Liu, 1998). However, it is still unclear what exactly happens in the human body, especially in the human brain under the Qigong state.

Functional MRI is an MRI technique that is based on an intrinsic contrast mechanism involving the different magnetic states of oxygenated and de-oxygenated hemoglobin, and has been used to image the brain's response to specific stimuli for more than 10 years. A few previous studies had demonstrated the potential application of fMRI and EEG in evaluation of Yoga or Meditation (Lazar *et al.*, 2000; Kakigi *et al.*, 2005). Therefore, it is possible to use fMRI to study Qigong. Because of some limitation of fMRI, the hemi-relative quantification, it was hard to study a specific continuous state like Qigong directly or in a routine way. In our research, we used peripheral pain stimulation as an intermedium to understand the changes of brain function under Qigong state.

Table 1. Summary of the Areas of Activity Revealed when Masters Received Pain Stimulation on Their Right Leg before Qigong Practicing

Brain Areas	Brodmann Area	Coordination			Volume	t Value	p Value
		x	y	z	(mm^3)		
Left frontal lobe		24	−8	30	296	4.84	0.001
	6, 8	8	36	48	1304	5.36	0.000
	8, 9	40	24	46	1000	6.66	0.000
	10	2	68	0	1464	6.84	0.000
	9	38	40	40	232	5.11	0.000
Left temporal lobe	21, 22	62	−14	−8	1400	7.63	0.000
Left parietal lobe	7	12	−68	48	512	4.84	0.001
	7, 40	40	−64	50	1816	5.92	0.000
Left occipital lobe	17, 18	10	−102	−4	568	6.18	0.000
Left fronto-parietal lobe	5, 7, 31	4	−44	48	312	4.20	0.003
Left fronto-temporal lobe	10, 11, 13, 44, 45, 46, 47	44	38	4	11368	7.24	0.000
Left temporo-parieto-occipital lobe	1, 2, 3, 13, 19, 21, 22, 37, 39, 40	58	−44	34	6144	6.79	0.000
Left thalamus, caudate nucleus		12	−2	18	1440	5.29	0.000
Left cerebellum		30	−40	−44	128	5.22	0.000
		36	−78	−38	128	4.52	0.002
		16	−84	−32	232	4.38	0.002
Right frontal lobe	11, 47	−38	38	-8	192	4.23	0.003
	6, 44, 45	−52	10	14	1664	6.99	0.000
	10, 46	−48	44	12	824	5.60	0.000
	10, 46	−40	36	20	632	4.62	0.001
Right temporal lobe	21, 22	46	24	4	416	4.97	0.001
	22	−58	8	−2	96	4.03	0.005
Right parietal lobe	2, 40	−50	−48	54	1744	5.71	0.000
	7	−8	−74	44	128	4.10	0.004
	7	−4	−60	58	80	4.00	0.005
Right occipital lobe	17, 18	−2	−94	−10	1152	4.57	0.001
Right fronto-parietal lobe	5, 7, 40	−20	−50	56	1344	7.64	0.000
Right temporo-occipital lobe	19, 20, 21, 22, 37	−56	−64	−8	3856	6.29	0.000
	19, 22, 39	−56	−56	14	704	4.97	0.001
Right temporo-parietal lobe	13, 40, 42	−56	−38	20	1072	8.22	0.000
	39, 40	−56	−50	38	800	5.03	0.001
Right thalamus		−18	−10	14	96	1.05	0.004
Right thalamus, lentiform nucleus		−16	−16	2	552	5.87	0.000
Right cerebellum		−12	−84	−34	1872	6.73	0.000

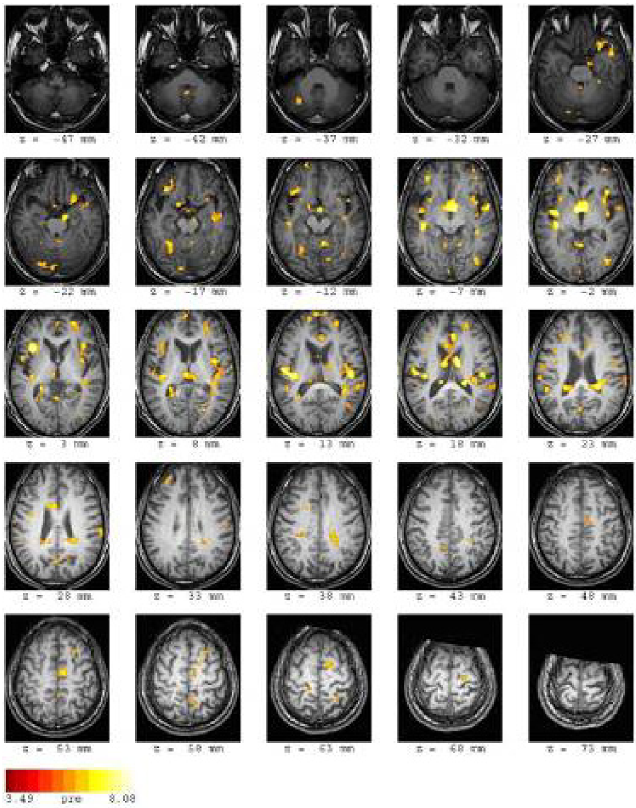

Figure 1. Brain activation map of masters who received pain stimulation on their right leg before Qigong practicing. Many functional regions were activated mainly at the SI and SII-insula regions, and many other Brodmann areas, the cigulate cortex, the thalamus, and the cerebellum were all activated.

Table 2. Summary of the Areas of Activity Revealed when Masters Received Pain Stimulation on Their Right Leg after 15 Min Qigong Practicing

Brain Areas	Brodmann Area	Coordination			Volume (mm^3)	t Value	p Value
		x	y	z			
Left frontal lobe	11	6	60	–20	224	5.74	0.001
	10, 11	20	64	0	1760	6.32	0.001
Left temporal lobe	21, 22	58	2	–10	192	4.88	0.004
Left fronto-parietal lobe	4, 6, 9, 43, 44	62	0	20	936	5.85	0.001
Left temporo-parietal lobe	13, 22, 40, 41, 43	66	–14	10	944	5.80	0.001
Left temporo-occipital lobe		44	–80	16	152	6.33	0.001
		–50	6	8	96	4.67	0.006
Right frontal lobe	11	–20	42	–14	104	4.92	0.004
	10	–26	50	12	176	4.72	0.006
Right temporal lobe	22, 38	–50	–4	–6	168	5.03	0.004
Right fronto-parietal lobe	3, 4, 6	–40	–16	60	432	5.00	0.004

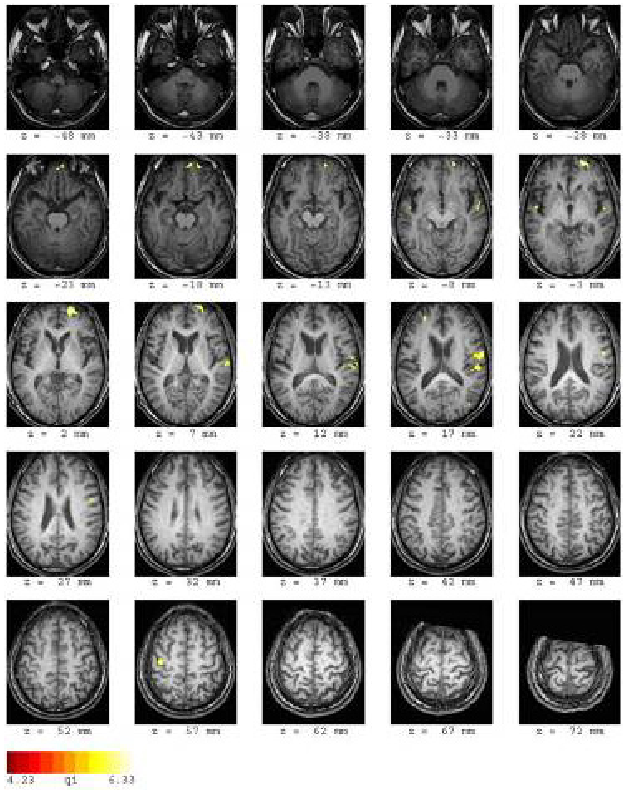

Figure 2. Brain activation map of masters who received pain stimulation on their right leg after 15 min Qigong practicing. Compared to the map of before Qigong practicing the activated areas were decreased obviously, which were mainly at the SII-insula region and some other Brodmann areas, the cigulate cortex and the thalamus were not activated.

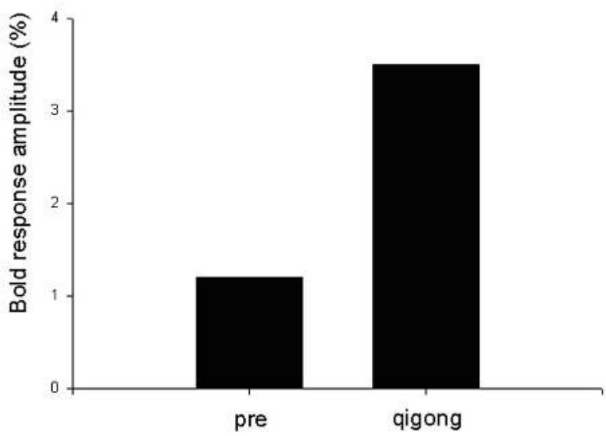

Figure 3. The response amplitude (percent BOLD signal change) of the SII-insula region. When under the state of Qigong (qigong) (3.5%), it was greater than that before Qigong (pre) (1.2%).

The pain reaction in the brain is a very complex physiological process. Apart from the common body sensation, other complex processes like cognition, attention, emotion, etc., all participate (Coghill *et al*., 1999; Zhang *et al*., 2001; Borsook and Becerra, 2006). In our study, the pain reaction of the masters' brain before Qigong practicing is extensive. Besides bilateral SII-insula region and left SI area, the areas that were associated with emotion, cognition, attention, etc., such as anterior cigulate cortex, thalamus, etc., and even SMA area were all activated. The result was almost the same with that reported in previous studies on pain reaction (Peyron *et al*., 2000; Guo and Yu, 2003).

After practicing Qigong for 15 min, according to the result from EEG, these maters were under Qigong status. And the activated areas of the pain reaction in the brain were decreased obviously, almost all the areas associated with cognition, attention and emotion disappeared, and only SII-insula regions and some SI-area were reserved. When the study finished, the masters were asked to report the feeling of the pain during the whole test procedure. They all felt painless during the Qigong state. Thus, our result from the fMRI study was compatible with the masters' subjective feeling of the pain.

The change of the pain reaction of the brain under Qigong state indicated that the main manifestation of the Qigong was the decrease of the excitability to circumstantial influence. The result was similar to that of EEG study. Therefore, we confirm once more that Qigong state does exist and the state is different to the normal conscious state. Moreover, we have reasons to believe that the main effect of Qigong state is a suppression of the pain reaction with the basal sensation reserved.

Furthermore, we also found that after Qigong practice, accompanied with the decrease of the activated areas, the response amplitude of SII-insula regions was increased. We do not know whether the result is an individual or universal phenomenon, and what is the physiological basis. We assume that this may be the result of blood flow redistribution when entering the Qigong status, the elevation of the excitability in some specific local region may due to the suppression of the major areas in the brain. Since our sample is still small, more studies are needed and the research result is yet to be further confirmed.

In conclusion, the pain reaction of the brain was changed when under Qigong state. The main manifestation of this kind of brain functional change is suppression of functional reaction. But, there is elevation of excitability in some specific local regions. Further study of the exact physiological mechanism is still needed.

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