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Effect of Taiji post-standing on the brain analyzed with EEG signals

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***Abstract*—**Taiji post standing is a supplementary exercise for Taiji, which aids the internal function of the body and brain. Taiji post standing is usually considered to be helpful for human health. However, few studies have explored the mechanism of this exercise using modern measurement devices. This study for the first time explores the effect of Taiji post-standing on the human brain with participants wearing EEG signal measurement devices. Based on our studies of participants, who were selected to practice three different Taiji posts, the experimental results provide evidence that standing Taiji posts can help people to relax, and they also found it easier to meditate. It is considered that this method of investigation can also be carried out for other Taiji exercises, and it will be possible to gain a greater understanding of the complex health regulation mechanism of Taiji.

Keywords: Taiji post standing, EEG signals, Wearable devices, Significance test

Introduction

Taiji's popularity has grown dramatically over the past few decades, and it is now identified by UNESCO as part of Chinese national intangible cultural heritage.[1-3] It is a traditional exercise that has a history of more than one thousand years.[4,5] The Taiji Post Standing exercise is usually considered as a necessary base that can also operate as a supplementary exercises for Taiji.[6,7] The earliest record of post standing can be found in Huang Di Nei Jing Su Wen[8] and is a "breathing essence, keeping spirit independently and muscle as one". 单击或点击此处输入文字。From a classic Chinese medicine perspective, post standing is thought to regulate the human body and spirit, which makes this technique suitable for modern experimental studies. Among different posts, Taiji post standing is an exercise used for aiding the internal function of the body and mind[9]. This is because the practice of Taiji post-standing requires people to cooperate with "imagination", which is usually considered helpful for the physical and the mental state. However, limited by suitable devices to determine what actual benefits this exercise truly generates, few studies have been undertaken to evaluate its effect on the human mind. It is our belief that understanding the effect of Taiji post-standing on the human brain is of great importance, and it may help reveal the regulation mechanism of Taiji post-standing in human health.

Previous studies have shown that brain function can generate electrical signals.[10-13] Through measuring these electrical signals, which are commonly named electroencephalogram (EEG) signals, the state of the brain can be assessed.[14-16] In many studies it has been used to determine emotion, and it is also useful for analyzing issues relating to brain development. However, with the development of wearable electroencephalogram (EEG) devices, the major advantage of this technique is the brain state can be directly measured in real-time, which can be extremely beneficial in sport science.[17-21] In this study, we carried out a tracking study on a select group of practitioners who undertook three different Taiji standing post exercises. These were directed by a master of Chen' Taiji for a period of thirty days. We then analyzed the changes in EEG signals that were caused by different posts, to reveal the influence of this exercise on the human mind. In addition, through

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comparing the effects caused by different exercises, the characteristics of different standing posts were summarized. This new study can aid Taiji post standing practitioners, to choose the appropriate exercise for their body.

Experiment and methods

A. Participants

With institutional review board approval, three eligible participants were selected for this preliminary study. These participants all had no prior experience of post-standing before this experiment. Three different Taiji posts were selected.

Following the traditional instruction from a master of Chen' Taiji, the first post (post-A) shown in figure 1a, requires the participant to keep one foot in front and the other behind, making feet like lunges, holding the arm in front as hugging a tree. Moreover, to ensure the correct gesture, the participant should sink their shoulders, hang the elbows, keep the belly in, empty collar, and have a loose waist feeling, like sitting on a stool. The second post (post-B) shown in figure 1b, requires the practitioner to keep the front and back foot dislocated (separated), standing with the back foot pointing 45° forward. Additionally, the participant should stand with knees slightly bent, keep the middle and ring fingers of both hands bent, with empty collar. The third post, (post-C) shown in figure 1c, requires the practitioner to keep their feet a shoulder-width apart, bend their knees, sink shoulders, hang elbows, empty collar, and press their hands as if pressing against a floating board.

B. Procedure

All participants of these three Taiji standing posts were required to practice around 20 minutes every day for one month. Meanwhile, to evaluate the effects of standing Taiji posts, EEG signal tracking measurements were done at 9:00 PM (UTC+8) every day. The EEG measurement experiments were carried out in an electromagnetic shielding room, where the sound and light were also blocked. Additionally, the test environment was clean and tidy, and the temperature and humidity were maintained around 26 ℃ and 35%~42%, respectively. The measurement experiments were conducted as follows. First of all, the EEG signals of the practitioners were measured for 2 minutes under quiet conditions. Then, 2 minutes EEG signal measurements of standing posts state were followed. After that, 2 minutes of post quiet measurements were done. To exclude the impact from daily effects of the body, average measurement results were used for further feature analysis.

To set up the EEG measurement system, self-developed single-channel wearable EEG devices were applied in this research. According to physical structure and related functions, the brain usually can be divided into four regions, the frontal lobe, parietal lobe, occipital lobe, and temporal lobe. Generally speaking, EEG signals from the prefrontal lobe[22] are mainly used to indicate attention and relaxation.[23-25] Based on the above theory, EEG signals of the prefrontal lobe were measured for analysis in this study. The EEG measurement diagram used in this study is shown in figure 2.

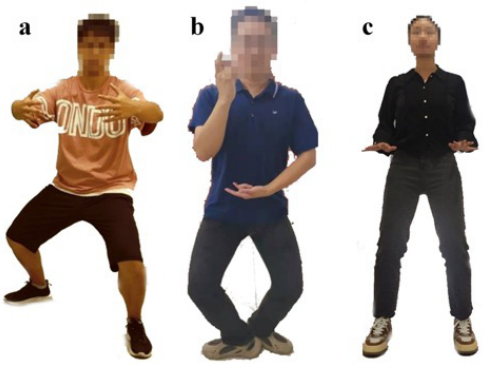

Fig. 1 Postural diagrams of three different Taiji posts, (a) post-A (b) post-B (c) post-C.

Fig. 2 EEG signal measurement device used in this study.

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C. Data analysis

Since the directly measured EEG signal is a type of non-stationary and weak electrical signal with only around 50pV, and the effective frequency range is 0.5~50Hz[26], it is necessary to analyze the EEG of different frequency bands and extract the characteristics of each frequency band to represent the different physiological activity states of the brain. Previous studies have proven that EEG signals can be classified into different bands, which are related to different states of the human brain shown in Table 1[27]. To explore the specific effects of different Taiji posts, all these bands are comprehensively considered in this study.

Table 1 EEG frequency band and its corresponding brain state.

EEG frequency band		Frequency range (Hz)	Frequency band properties
δ_1		0.5-2	Fatigue, lethargy
δ_2		2-4	Unconscious wave
θ		4-8	Subconscious level, deep meditation, inspiration
α_1		8-9	Consciousness gradually blurred
α_2		9-12	Physical and mental relaxation
σ		12-14	Vigilance
β_1		12-16	Relax but concentrate
β_2		16-20	Thinking
β_3		20-28Hz	Agitation and anxiety
γ		25-50	Meditate and raise awareness

The adopted EEG signal processing flow in this study is shown in figure 3.

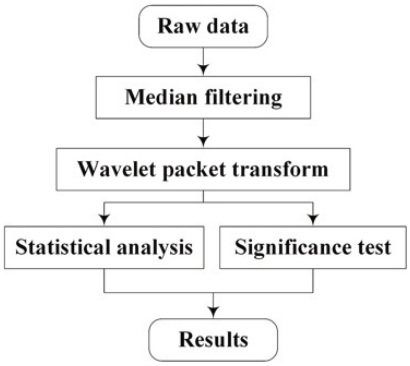

Fig. 3 EEG signal analysis process.

First of all, the raw data directly measured by devices usually contain error signals due to the effect of the measurement system. A median filter (which is a kind of data filtering method that can remove the errors mentioned above and retain the integrity of these data) was applied to obtain denoised data. Furthermore, the wavelet packet transform method was used to extract the frequency bands as in Table 1. After that, time-frequency statistical analysis was conducted to get a bird's-eye view of the influence results. To get more detailed information, a significance test was done using the T-test method with different time-domain features of each frequency band. The T-test was performed between two feature sequences before, during, and after posts standing, to determine whether there was a significant difference ($p <= 0.05$). The significantly influenced features were used to investigate the regulation mechanism of Taiji post-standing for human health.

In this study, three important time-domain features were finally selected and calculated, as shown in Table 2.

Table 2 EEG features and their calculation expressions.

Features		Functions
Average value (ARV)		$\bar{x} = \frac{1}{n}\sum_{j=1}^{n} x_j$
Root mean square (RMS)		$RMS(x) = \sqrt{\frac{1}{n}\sum_{j=1}^{n} \lvert x_j \rvert^2}$
Renyi Entropy (RE)		$RE_{alpha} = -\log\left(\sum_{i=1}^{K} P_{alpha}(f_i)^2\right)$

Results

A. Time-frequency analysis results for different posts

Through applying the short-time Fourier transform (STFT) to those denoised EEG signals, the amplitude distribution maps in different frequencies and times were plotted for different posts.

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Taiji Post-A

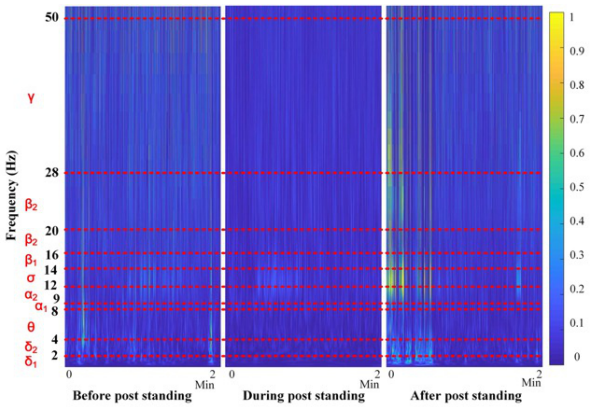

Fig. 4 Time-frequency analysis result for standing Taiji post-A.

The time-frequency analysis result of Taiji post-A is shown in figure 4. For Taiji post-A, EEG signal intensity of all frequency bands during the standing process is more balanced than that seen before and after the post standing processes. In addition, during the standing process the intensity for high frequency (>14Hz) is lower than seen in other processes.

Taiji Post-B

From the time-frequency analysis result of Taiji post-B shown in figure 5, the balance effect of EEG signal intensity during the standing process is more significant than post-A. Moreover, this effect can last longer after standing process. Obviously, the intensity for high frequency (>14Hz) is also lower during the standing process than in other processes.

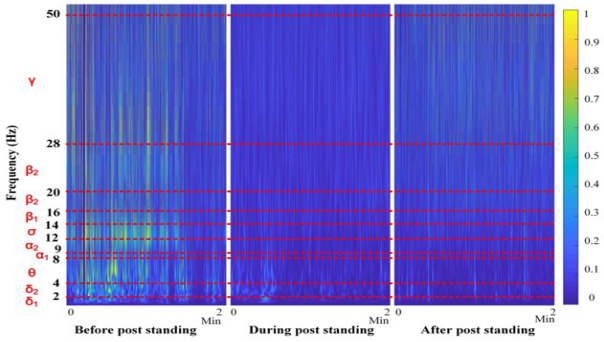

Fig. 5 Time-frequency analysis result for standing Taiji post-B.

For Taiji post-C, the EEG signal intensity of low frequency (<14) during the standing process becomes higher than other processes, which is different than other posts. However, EEG signal intensity of all frequencies after post-standing is more balanced.

Taiji Post-C

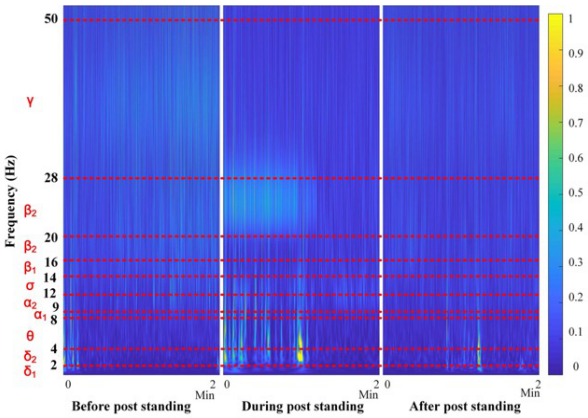

Fig. 6 Time-frequency analysis result for standing.

From these time-frequency analysis results, it is obvious that a standing post can help the brain enter into a rest state as indicated by the balanced intensity. However, for different posts, the results are varied, which need further discussion.

B. Significant test results for different posts

To gain more detail about effects caused by the different post positions, a T-test method was used for significant tests to select parameters for comparison. For different posts, the same phenomenon was found

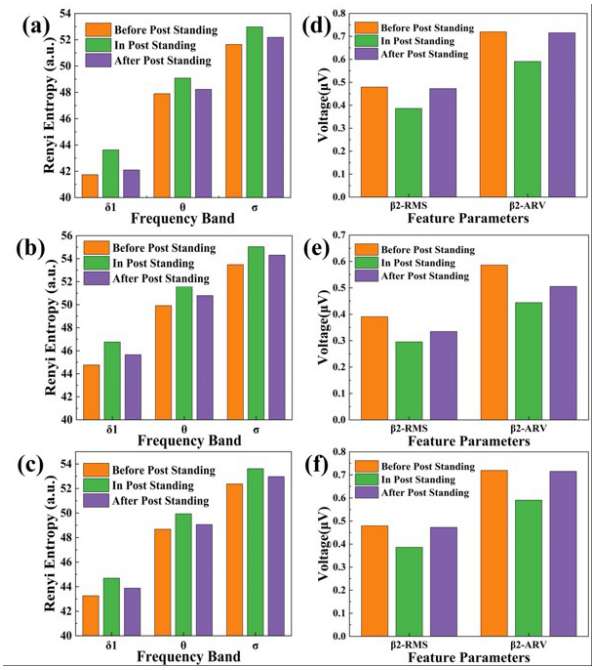

Fig. 7 Renyi entropy values change in different states of (a) Taiji post-A, (b) Taiji post-B, and (c) Taiji post-C; The average and root mean square values of β_2 for (d) Taiji post-A, (e) Taiji post-B, and (f) Taiji post-C.

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that the Renyi Entropy values of δ_1, θ and σ are all significantly increased during the post standing process as shown in figure 7. In addition, we found that δ_1, θ and σ are all low frequency (<14Hz) bands.

For high-frequency region (>14Hz), the average and root mean square values of β_2 are significant features. These values all became lower during the post-standing process, for all posts.

Discussion

In this study, to analysis, the EEG signals changes caused by standing different Taiji posts, time-frequency and significant tests were carried out. From the EEG intensity of different frequency bands, the change trends caused by standing posts are similar for different posts. This phenomenon may indicate that all posts have a similar ability to relax the human mind. However, the low frequency (<14Hz) bands signals for post C increased a small amount, which is closely related to the requirement to imagine pressing a floating board during the practice session. Through significant tests, the Renyi entropy of δ_1, θ, and σ are all changed in some trends. On one hand, these results indicate three of those parameters can be considered as key parameters to evaluate the effect of standing Taiji posts for humans. On the other hand, since those parameters are usually used to evaluate the meditation and relaxation states of humans, these data show that standing Taiji posts can help people to enter into those states. However, between the different posts there are differences, which may be caused by slight differences in the practice methods. In addition, many features at other frequency bands are not discussed in this study. Thus, based on this pioneering study other parameters can be used to explore other effects of standing Taiji posts.

Conclusion

Through measuring and analyzing the EEG signals of participants in different processes of standing Taiji posts, this study found evidence that argues Taiji posts can help people to become relax and enter into a meditation state. The Renyi entropy of δ_1, θ, and σ bands increased during the standing process for all posts, which indicated those bands are more active. Those frequency bands are usually considered to be related to relaxation and meditation states from previous studies. The average and root mean square values of β_2 is lower during the Taiji posts standing process. β_2 is a kind of frequency band that is related to relaxation and concentration, which indicates all participants were relaxed. This study provides a modern measurement method to investigate the effects of standing Taiji posts and some features were shown to change in the same trend for different posts. Based on this method, other feature parameters to evaluate the effects of other posts also can be investigated in the future.

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