ORIGINAL ARTICLE

Psychiatry and Clinical Psychopharmacology 2024;34(1):1-8
DOI:10.5152/pcp.2024.23702

# Exploring the Effects of Repetitive Transcranial Magnetic Stimulation on Comorbid Sleep Disorders in Preschool Children with Attention-Deficit Hyperactivity Disorder

**Jiang Yilin[1], Zhou Heng[2], Zou Fei[3], Liu Jiayang[1]**

*[1]University Teknologi Malaysia, Faculty of Education, Johor, Malaysia; [2]Department of Student Affairs, Chongqing Medical University, Chongqing, China; [3]Chongqing University of Education, School of Teacher Education, Chongqing, China*

## ABSTRACT

**Background:** Attention-deficit hyperactivity disorder (ADHD) is one of the most common neurological developmental disorders in children, and sleep disorders (SDs) are a common comorbidity in children with ADHD. There are currently no pharmacological treatment options for SD in children with ADHD of preschool age (4-6 years). Repetitive transcranial magnetic stimulation (rTMS) is a novel, non-invasive neuromodulation technique. This study explores the effectiveness of rTMS for comorbid SDs in preschool-aged children with ADHD.

**Methods:** Thirty-five children of preschool age with ADHD and comorbid SDs were recruited for this study. The children were divided into a parent behavior management training (PBMT) group (n = 19) and a repetitive transcranial magnetic stimulation combined with parent behavior management training group (n = 16). Both groups underwent 8 weeks of treatment. The children's SD scores were assessed using the Chinese Children's Sleep Habits Questionnaire, were measured before the start, at the end, and 4 weeks after the end of the intervention, and were used to measure the effects. Within-group differences were compared using a repeated-measures analysis of variance, and between-group differences were compared using an independent samples *t*-test and Mann–Whitney *U*-test.

**Results:** Both the PBMT group and the rTMS combined with the PBMT group significantly improved the SDs of preschool-aged children with ADHD ($P < .001$), but the effect of the intervention was more pronounced in the rTMS combined with the PBMT group ($P < .001$) and lasted longer than the PBMT group ($P = .004$).

**Conclusion:** Repetitive transcranial magnetic stimulation is a promising non-pharmacological therapy to improve SD in preschool-aged children with ADHD.

## ARTICLE HISTORY

**Received:** April 21, 2023
**Revision requested:** May 31, 2023
**Last revision received:** September 11, 2023
**Accepted:** September 24, 2023
**Publication Date:** February 1, 2024

## INTRODUCTION

Attention-deficit hyperactivity disorder (ADHD) is a neurodevelopmental disorder characterized by excessive amounts of inattention, hyperactivity, and impulsivity that are pervasive, impairing in multiple contexts, and otherwise age inappropriate.[1] It is categorized into 3 different subtypes: predominately inattentive, predominately hyperactive, and the combined type.[1,2] Attention-deficit hyperactivity disorder is one of the most prevalent neurodevelopmental disorders, with a worldwide prevalence of about 7%.[3] In China, the prevalence of ADHD in children is about 6.26%, showing an overall high prevalence, low consultation rate, low treatment rate, and underdeveloped clinical treatment capacity.[4,5] Particularly in recent years, due to the impact of the epidemic, children with ADHD are receiving online distance learning at home, which has resulted in a lack of peer support, disruption of existing routines, and excessive screen exposure, exacerbating the symptoms of children with ADHD.[6] In addition to poor academic performance, poor peer relationships, dysfunctional families, substance abuse, early sexualization, and high rates of delinquency are all common among children with ADHD.[3,4,7] Furthermore, 15-65% of children with ADHD have symptoms that persist even into adulthood and continue throughout their lives.[8] This shows that ADHD is developmental and persistent and can cause immeasurable damage to the development of the child and the future adult.

Attention-deficit hyperactivity disorder is characterized by extremely high rates of comorbidity, with approximately two-thirds of children with ADHD suffering from comorbidities including, but not limited to, sleep disorders, depression, anxiety disorders, bipolar disorder, autism

**Corresponding author:** Yilin Jiang, e-mail: yilinjiangs@foxmail.com

**Cite this article as:** Yilin J, Heng Z, Fei Z, Jiayang L. Exploring the effects of repetitive transcranial magnetic stimulation on comorbid sleep disorders in preschool children with attention-deficit hyperactivity disorder. *Psychiatry Clin Psychopharmacol.* 2024;34(1):1-8.

spectrum disorders, and delayed language function.[9,10] The most prevalent comorbidity is sleep disorders with approximately 73% of children with ADHD suffering from sleep disorders. Some specific symptoms of sleep disorders include, but are not limited to, difficulty falling asleep, night waking, sleep resistance, difficulty waking, daytime sleepiness, nightmares, sleepwalking, and restless legs syndrome.[10,11] In addition, data has indicated a rising trend in recent years.[6,12]

The relationship between ADHD and SD appears to be bidirectional. If SD in children with ADHD is not effectively treated, this can exacerbate the core symptoms of ADHD and even bring about other developmental disorders.[13] At the same time, it has also been suggested that the core symptoms of children with ADHD can be improved by intervening with SD in children with ADHD.[14] The reasons why children with ADHD are more likely to suffer from SD than their peers are complex, and there are no uniform findings, but evidence has been found from neurobiological perspectives, family environment, and medication side effects.[15,16] Overall, the prevalence of SD in children with ADHD is exceptionally high. In such cases, it is desirable that appropriate and effective SD interventions are introduced promptly. This will help to improve the core symptoms of ADHD, reduce the risk of other complications, and help the child to develop.

Current interventions for the core symptoms and comorbidities of SD in children with ADHD have focused on both pharmacological and non-pharmacological treatments.[17] However, medication, which is extremely easy to build a tolerance to and has some side effects, has also been reported to increase the risk of SD in patients taking medication for ADHD.[5,13,15] At the same time, most countries do not have FDA-approved (Food and Drug Administration) medications for SD in children under 16 years of age.[5] This makes the use of pharmacological interventions for SD in children with ADHD in the younger age groups controversial and difficult to implement.

**MAIN POINTS**

- About 15-65% of children with attention-deficit hyperactivity disorder (ADHD) have symptoms that persist even into adulthood and continue throughout their lives.
- The most prevalent comorbidity is sleep disorders, with approximately 73.00% of children with ADHD suffering from sleep disorders.
- If sleep disorders (SD) in children with ADHD are not effectively treated, this can exacerbate the core symptoms of ADHD and even bring about other developmental disorders.
- Repetitive transcranial magnetic stimulation combined with parent behavior management training appears to be more effective, as it not only provides more significant relief of SD symptoms in children with ADHD but also leads to a longer duration of treatment effects.
- All parents reported a lack of knowledge about ADHD and its comorbidity SD in this study.

Among the non-pharmacological therapies are EEG biofeedback (Electroencephalography), cognitive behavioral therapy, physical exercise, combination therapy approaches, and parental behavior management training.[9,17] Among these, parental behavior management training (PBMT) is recommended by several manuals and expert consensus, recommending it as the preferred option in the non-pharmacological treatment of SD in children aged 4-6 years with ADHD.[4] In addition, the practice of PBMT has been gaining popularity in recent years.[10,18] Among the non-pharmacological treatment options, non-invasive neuromodulation techniques such as repetitive transcranial magnetic stimulation (rTMS) have received extensive research and attention in the last decade due to their high safety, efficacy, and long duration of effect.[9,17,19] Repetitive transcranial magnetic stimulation has been shown to be effective for SD in adult patients with ADHD and comorbid SD in children with autism spectrum disorders.[19,20,21,32] Therefore, it is a promising approach to SD intervention for children, especially preschool (4-6 years) children with ADHD.[22]

This study will compare the effectiveness of PBMT and rTMS combined with PBMT for sleep disorders in children with ADHD of preschool age (4-6 years). We hypothesize that the combined therapy making use of rTMS will be more advantageous in terms of the effectiveness of the treatment as well as the continuity of its effects.

## MATERIAL AND METHODS

### Participants

Thirty-five children with ADHD whose parents underwent PBMT at a maternal and child health hospital in a city in western China from June 2022 to October 2022 were selected. All participants were recruited through posters placed in the hospital and volunteered to take part. All parents gave consent for their children to undergo rTMS. All volunteers were admitted to the study, and no participants dropped out during the course of the study. The participants were divided into an experimental group (the rTMS combined with the PBMT group) and a comparison group (the PBMT group) according to their parents' wishes, with 16 in the experimental group and 19 in the comparison group. Experimental group: 10 (62.50%) males and 6 (37.50%) females. Comparison group: 12 (63.16%) males and 7 (36.84%) females. The experimental and comparison groups were: 5.16 (4.02-6.10) and 5.10 (4.30-6.50). The primary caregivers in both groups were the parents, i.e., the participants involved in the PBMT (see Table 1). The prevalence of comorbidity of SD in children with ADHD in these groups is consistent with previous research findings.[10,11] Moreover, there were no significant differences in SD between the 3 ADHD subtypes.

**Inclusion criteria:** (i) Children must meet both the diagnostic criteria for ADHD in the DSM-5 (The Diagnostic

**Table 1.** Information on Demographic Variables of Participants (n = 35)

| Variables | Experimental Group, n (%) or median(IQR) | Comparison Group, n (%) or median(IQR) | Chi-square *P* |
|---|---|---|---|
| *Gender* | | | .501 |
| Male, n(%) | 10 (62.50) | 12 (63.50) | |
| Female, n(%) | 6 (37.50) | 7 (36.50) | |
| Age (years), median(IQR) | 5.16 (1.9) | 5.10 (2.2) | |
| Caregiver | Parents | Parents | |

Table 1 shows the demographic variables of the subjects, including gender and age (years). Due to the non-normal distribution of the age data, the median (IQR) presentation was chosen.
The chi-square test ($P > .05$) revealed that there was no difference in scores between the different genders in the experimental and comparison groups.
As the main participants in this study's PBMT (Parent behavior Management Training) were parents, the primary caregivers of the subjects were indicated as parents. IQR, interquartile range.

and Statistical Manual of Mental Disorders 5th Edition) published by the American Psychiatric Association in 2013 and the diagnostic criteria for sleep disorders in the International Classification of Sleep Disorders (third edition) in 2014 and the Chinese Sleep Health Guidelines for Children 0-5 years old in 2017. (ii) Age 4-6 years old, regardless of gender (iii) Typical clinical symptoms such as sleep resistance, difficulty falling asleep, the habit of sleeping late, frequent night waking, night terrors, excessive early awakening, short sleep duration, disturbance of circadian rhythm, and daytime sleepiness. (iv) No medication for ADHD, exogenous melatonin, antipsychotics, sedatives, or hypnotic drugs to have been taken within 1 month of the treatment beginning. (v) Informed and signed consent from a guardian who voluntarily allows the child to participate in this study and whose caregiver cooperates with the study.

In this study, we need to exclude organic causes and contraindications to rTMS that may lead to sleep disorders, namely: (i) organic lesions of the brain, e.g., multiple cerebral tenderness, cerebral leukodystrophy, malformations of brain development; (ii) chromosomal or genetic abnormalities co-occurring with ASD, e.g., Rett syndrome, childhood disintegrative psychosis, Angel syndrome, fragile X syndrome, tuberous sclerosis; (iii) organic diseases of the respiratory system, e.g., sleep-related breathing disorders caused by anatomical abnormalities (e.g., airway stenosis, tonsillar hypertrophy), local tissue compliance problems; (iv) people with comorbid epilepsy; and (v) contraindications to rTMS, e.g., post-cochlear implantation, increased intracranial pressure or intracranial infection, intracranial metallic foreign bodies, etc.

The implementation guidelines in the PBMT contain specific methods for managing children's sleep and daily actions. The details of the process must be shared and recorded in online groups on social media. The researchers maintain the right to ask participating parents to withdraw from the program if they refuse to implement it or cannot do so due to other irreversible factors. The final results will also not be included in the analysis of the experimental data.

The PBMT for this study was conducted at the Child Psychology Department of the hospital, and the online training was conducted on an encrypted webcast platform. All participating parents signed an informed consent form, agreeing to participate in the experiment and to allow the data to be used as material for a non-profit scientific research project. All experiments were performed in accordance with relevant guidelines and regulations. The Chongqing SPBD Maternal and Child Health Hospital ethics committee approved the study (Approval number: CQSPB-20220402).

## Assessment Tools

In this study, an adapted edition of the Chinese version of the Children's Sleep Habits Questionnaire was used, recommended by the Chinese Health Care Commission (CHCC) for the assessment of children's sleep problems and has sound reliability and validity.[23] Furthermore, the Recommendation Manual by CHCC solely emphasizes the significance of the total score but does not break down the specific dimensions. The original version of the questionnaire contained 8 dimensions: sleep resistance, delayed sleep onset, sleep duration, sleep anxiety, nocturnal awakening, heterogeneous sleep, sleep breathing disorder, and daytime sleep. These 8 dimensions encompass most of the characteristics of sleep disorders in children with ADHD mentioned in the previous section. The questionnaire is based on a 3-level scale with 34 questions. A total score of more than 54 indicates that the child has a sleep disorder that requires further pathological diagnosis. The higher the score, the more severe the sleep disorder. The Cronbach's alpha coefficient of the initial questionnaire was 0.56-0.93; the Chinese version had a Cronbach's alpha coefficient of 0.84; and the Cronbach's alpha coefficient for the questionnaire in this study was 0.85.

## Intervention Methods

After the parents signed the informed consent form, an 8-week PBMT was conducted for the comparison group parents. The PBMT was conducted twice a week, the first 4 offline and the last 4 online, with the content designed by an experienced psychotherapist in conjunction with a pediatrician, as detailed in Table 2.

The experimental group conducted rTMS in combination with PBMT for parents. The rTMS was operated by the researcher in the hospital using low-frequency stimulation of the right dorsolateral prefrontal area for 20 minutes per session, 3 times per week, for 4 weeks. Parents in the experimental group attended the PBMT at the same

**Table 2.** Parental Behavior Management Training Outline

| Duration | Contents | Location |
|---|---|---|
| One hour | ADHD Basics | Group psychological counseling room |
| One hour | ADHD and SD Basics | Group psychological counseling room |
| One hour | SBMS (theory) | Group psychological counseling room |
| One hour | SBMS (hands-on) | Group psychological counseling room |
| One hour | PCCS | Online conference system |
| One hour | SBMS (replay) | Online conference system |
| One hour | PCCS | Online conference system |
| One hour | SBMS (hands-on) | Online conference system |

Table 2 shows the arrangement and duration of the PBMT used in this study. Because there are no authoritative guidelines available, the content is designed by the relevant experts and shows the outline of the relevant topics.
Due to the recurrence of the epidemic, the first 4 PBMTs were conducted in the hospital's group psychological counseling room and the last 4 were conducted remotely in the online conference system.
ADHD, attention-deficit hyperactivity disorder; PCCS, Parent-Child Communication Skills; SBMS, Sleep behavior Management Skills.

time as parents in the comparison group. The selection of treatment parameters for this study was based on the recommendations of relevant manuals and valid parameters from previous studies and adjusted in conjunction with expert advice.[22,32,33]

The specific treatment steps of rTMS are as follows: rTMS (Model YRD.CCY-III, circular coil, frequency 1Hz) threshold determination, the first rTMS treatment requires the determination of the resting motor threshold (RMT), and the determination steps are: first, correctly wear the positioning cap; the intersection of the naso-occipital line (the line from the root of the nose to the posterior occipital ridge); and the temporoparietal line (the line between the 2 zygomatic arches at the end of the depression) is the child's C2 point, ensuring that the child's C2 point coincides with the C2 point drawn on the cap. Motor-evoked potentials were then recorded using a special rTMS motor-evoked potential electrode line, with the recording electrode placed on the ventral part of the thumb short adductor muscle, the reference electrode on the distal end of the tendon, and the grounding electrode on the wrist. The center of the circular coil was positioned directly over the C2 point (stimulation of this point optimally evoked movement of the right short thumb flexor). Then, using a single pulse pattern stimulation, 10 stimulations, 5 of which evoked the thumb-split muscle movement (leading to an evoked potential of 50 μV or more in the thumb-split muscle), and the intensity of this stimulation was the resting motor threshold. Considering the stage of development of the cerebral cortex and the stage of language ability in children, a relatively low-frequency treatment parameter was chosen: stimulating the right prefrontal dorsolateral area at 1 Hz with a fixed intensity of 40% × 90% × 2.88 T, 1000 pulses per second, 10 seconds of stimulation, 10 stimuli, 10 seconds of the interval, 45 repetitions, and a treatment time of 20 minutes per session. To ensure accurate positioning of the rTMS coil, the child was given a positioning cap marked with an anatomically defined stimulation location, and the stimulation coil was placed at 45 degrees to the surface of the child's skull with the center of the circle placed at the stimulation point in the dorsolateral area of the right prefrontal lobe (i.e., the scalp area of F4 in the international standard EEG 10-20 system). Repetitive transcranial magnetic stimulation positioning is shown in the attached Figure 1.

## Statistical Analysis

Statistical analysis was performed using IBM Statistical Package of the Social Sciences Statistics software version 25.0 (IBM SPSS Corp.; Armonk, NY, USA), and for non-normally distributed variables, medians and interquartile ranges (IQRs) were reported, and for normally distributed

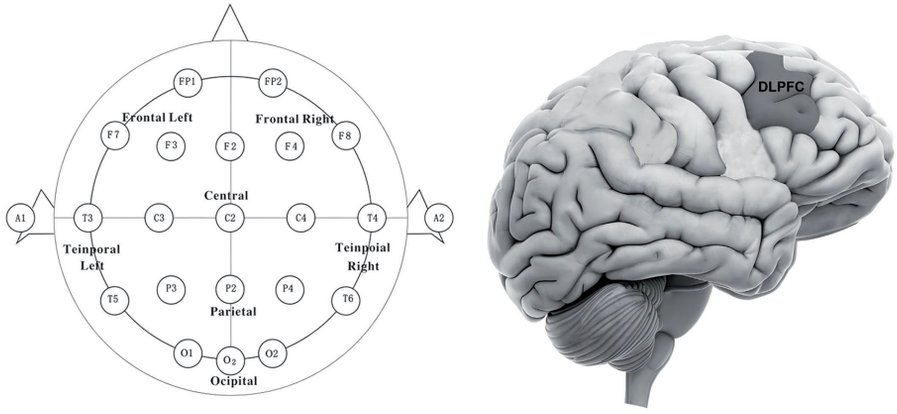


Figure 1. Repetitive transcranial magnetic stimulation localization map and area of action. Figure 1, on the left, shows the brain localization points during instrumentation; on the right, the right dorsolateral prefrontal cortex, the brain region targeted by repetitive transcranial magnetic stimulation.

**Table 3.** Comparison of CHSQ Scores Between Different Groups

| Groups | Pretest, Mean (SD) | Posttest PR (%), Median (IQR) | Tracking-test PR (%), Median (IQR) |
|---|---|---|---|
| Experimental group | 68.56 (8.90) | | |
| PR (%), median (IQR) | | 21.32 (17.96) | 18.03 (18.2) |
| Comparison group | 66.42 (9.50) | | |
| PR (%), median (IQR) | | 13.01 (11.08) | 5.36 (17.09) |
| *P* | .469 | .004* | .003* |

Table 3 demonstrates, for the experimental and comparison groups, the comparison between the groups. The raw score data are presented using mean (SD) as they conform to a normal distribution, and the baseline is compared using an independent samples *t*-test; the rate of progress is presented using median (IQR) as it does not conform to a normal distribution and is compared using the Mann–Whitney *U*-test; a difference of $P < .05$ is considered significant. CHSQ, Children's Sleep Habits Questionnaire; IQR, interquartile range; PR, progress rate compared to pretest baseline, (posttest or tracking test—pretest)/pretest. *$P < .05$.

variables, means and SDs were reported. Descriptives of categorical variables were reported as n (%). The Shapiro-Wilk test was used for the test of normal distribution. The chi-square test was used to test whether there was a difference in scores between the different genders in the experimental and comparison groups. The Mauchly's test was used to check the homoscedasticity of the data. A repeated-measures analysis of variance was used for within-group variation and an independent samples *t*-test for between-group differences. The least significant difference (LSD) correction was used. The difference was considered statistically significant at $P < .05$. Meanwhile, when making between-group comparisons, the progress rate (PR) was chosen as the primary comparative indicator of between-group differences; the PR equals the ratio of posttest or tracking-test minus pretest (baseline), divided by pretest. If the statistics were not normally distributed, the Mann–Whitney *U*-test was used for the analysis of differences. The difference was considered statistically significant at $P < .05$.

## RESULTS

After the 8-week intervention, the CHSQ scores decreased in both the experimental and comparison groups (Table 4, $P < .001$, $P < .001$), indicating that both the experimental group (rTMS combined with PBMT) and the comparison group (PBMT) achieved good results. However, the difference in scores between the experimental group and the comparison group was significant (Table 3, $P = .004$), suggesting that although both programs achieved positive results, the experimental group achieved a better intervention effect. A tracking test was administered 4 weeks after the end of the intervention and showed that the difference between the scores of the experimental group and the comparison group was significant (Table 3, $P = .003$). Furthermore, the tacking scores of the experimental group were still significant compared to the pretest (Table 4, $P < .001$), but the comparison group was no longer significant (Table 4, $P = .067$). This fluctuation suggests that although the PBMT and the PBMT combined with rTMS positively affected the targeted symptom in the short term, the PBMT combined with rTMS had better persistence for SD in children with ADHD.

## DISCUSSION

The posttest results of this trial illustrate that both types of interventions are effective. However, rTMS combined with PBMT appears to be more effective, as it not only provides more significant relief of SD symptoms in children with ADHD but also leads to a longer duration of treatment effects. The combination of multiple treatment options seems to have a remarkably high potential for the treatment of children with ADHD compared to a single treatment option, whether it is a combination of pharmacological and non-pharmacological treatments or a combination of purely non-pharmacological treatments. As long as the combination is administered scientifically, it can improve the various symptoms of children with ADHD significantly.[2,21]

**Table 4.** Comparison of CHSQ Intra-Group Scores by Group (n = 35)

| Groups | Scores, Mean (SD) | Matching Criteria | Mauchly's *P* | ANOVA *P* | Paired *P* |
|---|---|---|---|---|---|
| Experimental group | | | .265 | <.001** | |
| Pretest | 68.56 (8.90) | T0-T1 | | | .001** |
| Posttest | 52.50 (5.23) | T1-T2 | | | .181 |
| Tracking test | 55.65 (4.54) | T2-T0 | | | <.001** |
| Comparison group | | | .363 | .002** | |
| Pretest | 66.42 (9.50) | T0-T1 | | | <.001** |
| Posttest | 56.89 (4.63) | T1-T2 | | | .036* |
| Tracking test | 62.00 (6.90) | T2-T0 | | | .067 |

Table 4 mainly shows the differences within the experimental and comparison groups, which were analyzed using repeated-measures ANOVA, with $P < .05$ being a significant difference. ANOVA, analysis of variance; CHSQ, Children's Sleep Habits Questionnaire; T0, pretest; T1, posttest; T2, tracking test. *$P < .05$. **$P < .01$.

The DSM-5 classification of ADHD as a neurodevelopmental disorder reflects the continuity between childhood and adult mental disorders, with the diagnostic classification of childhood mental disorders being consistent with that of adults, emphasizing that ADHD is a chronic mental disorder that can persist over a lifetime and requires long-term treatment.[1] Earlier identification and appropriate intervention are critical parts of the treatment of ADHD. However, both direct interventions for preschool-aged children with ADHD and interventions for their sleep disorders are complicated. Firstly, most countries do not approve the use of medication for ADHD or sleep disorders in preschool children. Although some studies have explored the effectiveness and safety of medication for preschool children with ADHD, more data and research are needed.[18] In addition, parents do not use medication as a first choice for children with ADHD due to concerns about side effects.[5] Therefore, as a non-pharmacological treatment, rTMS has become a promising option.[17] Most trials of rTMS intervention for sleep disorder-related problems have chosen a protocol that uses low-frequency stimulation on the right DLPFC,[24] and this study also chose a low-frequency protocol on the right DLPFC. The reason why low-frequency on the right DLPFC can relieve SD in children with ADHD is that rTMS in this area can improve sleep by increasing serum brain-derived neurotrophic factor and GABA concentrations and decreasing motor-evoked potentials.[25] It has also been suggested that rTMS can decrease serum cortisol, adrenocorticotropic hormone, and thyroid-stimulating hormone concentrations by modulating the hypothalam ic-pituitary-adrenal axis and thyroid axis function. At the same time, rTMS can also increase pineal melatonin secretion and brain concentrations of norepinephrine and 5-hydroxytryptamine, essential in maintaining normal sleep rhythms.[26,27] In addition, low-frequency rTMS promotes ipsilateral hippocampal nerve regeneration and reduces apoptosis, increasing its functionality and plasticity, which also facilitates the adjustment of sleep-wake disorders.[19,27] In summary, low-frequency rTMS stimulation of the right DLPFC has been shown to have an intervention effect by modulating the anterior cingulated cortex connectivity in the meso-cortical-limbic circuit and the GABAergic and glutamatergic circuitries.[28,29,30] rTMS has not been used for a long time in the treatment of ADHD and its comorbidities, but reports of adverse side effects of rTMS are uncommon. Occasionally, pressure and allergies due to the device being worn on the head have been reported.[19] This detail was also taken into account in this study, so that the adaptation time and adjustment time for the pediatric patients were increased, and consequently, no discomfort was reported by the pediatric patients or their parents during or after the treatment.

Although the core symptoms of ADHD did not improve in the children in this study, this may be because the duration of treatment for ADHD did not reach the 1-2 years recommended by the DSM-5, and this research is solely aimed at sleep disorders. However, throughout the treatment for sleep disorders, caregivers generally reported understanding more about ADHD and having a more positive outlook on their children's diagnoses. This provides a sound basis for follow-up treatment. Caregivers' beliefs and knowledge about ADHD and its comorbidities play a crucial role in the rehabilitation and treatment of children with ADHD, both in compliance and daily behavioral management. However, most parents' knowledge about childhood ADHD and its comorbidities is currently inadequate, especially in developing or relatively underdeveloped countries.[2,5,31] At the time of the PBMT in this study, parents reported a lack of knowledge about ADHD and its comorbidity SD, even though they exhibited proactive healthcare-seeking behaviors. Therefore, the dissemination of knowledge about ADHD should be given more attention. For example, increasing the number of lectures in primary schools or preschools, or even adding an assessment of ADHD and other prevalent diseases to teacher qualifications, could help teachers or caregivers to provide timely and effectively targeted help to children at an earlier stage. In addition, although many manuals recommend the PBMT, the effectiveness is largely limited by the level of parental literacy and the level of designers and trainers, and most current manuals do not contain operational PBMT methods and programs.[32] Finally, most studies seldom mention differences in sleep disorders across ADHD subtypes, due to the following reasons: (1) different subtypes of ADHD are all afflicted with sleep disorders and (2) it may be due to the limitations of the diagnostic criteria for ADHD concerning the limitations of sleep disorders in children.[33] It is hoped that more research will be conducted in the future to improve or address these issues and provide more practical and precise treatment options.

This study explored rTMS combined with PBMT to improve SD in preschool children with ADHD. Although some results were achieved, there are still limitations to this experiment, for example, knowledge of the specific brain mechanisms and specific pathways by which rTMS improves SD in children with ADHD and what the effect of rTMS on specific components of sleep in children with ADHD is. In addition, this study should have explicitly discussed issues such as parents' sleep habits and quality and the effect of religious beliefs on sleep habits. The results of this study can only be applied to preschool-age children whose parents also receive PBMT. Hopefully, subsequent studies will build upon this and bring about more meaningful advances in treating children with ADHD.

**Data Availability:** The data that support the findings of this study are available from the corresponding author upon reasonable request.

**Ethics Committee Approval:** The study was approved by the Chongqing SPBD Maternal and Child Health Hospital Ethics Committee (Approval No: CQSPB-20220402, Date: April 2, 2020).

**Informed Consent:** All participants and their parents have signed an informed consent form agreeing to the use of the data provided for this study.

**Peer-review:** Externally peer-reviewed.

**Author Contributions:** Concept – J.Y.; Design – J.Y.; Supervision – Z.H.; Resources – Z.H.; Materials – L.J.; Data Collection and/or Processing – Z.F.; Analysis and/or Interpretation – Z.F.; Literature Search – J.Y.; Writing – J.Y.; Critical Review – Z.H.

**Acknowledgments:** Thanks to Yilin Jiang PhD supervisor, Narina A. Samah, for giving me the greatest support. Thanks to the language expert Gisela Zipp from Rhodes University. Thank you to all the children and their parents who participated in this study.

**Declaration of Interests:** The authors have no conflict of interest to declare.

**Funding:** The authors declared that this study has received no financial support.

## REFERENCES

1. American Psychiatric Association. *Diagnostic and Statistical Manual of Mental Disorders*. 5th ed. Washington DC: American Psychiatric Association; 2013. [CrossRef]
2. Pipe A, Ravindran N, Paric A, Patterson B, Van Ameringen M, Ravindran AV. Treatments for child and adolescent attention deficit hyperactivity disorder in low and middle-income countries: a narrative review. *Asian J Psychiatr*. 2022;76:103232. [CrossRef]
3. Thomas R, Sanders S, Doust J, Beller E, Glasziou P. Prevalence of attention-deficit/hyperactivity disorder: a systematic review and meta-analysis. *Pediatrics*. 2015;135(4):e994-1001. [CrossRef]
4. Yang L. Research status and outlook of attention deficit hyperactivity disorder in 2017-2019. *The Chin J Ment Health*. 2020;34(7):8. [CrossRef]
5. Fan X, Ma Y, Cai J, et al. Do parents of children with ADHD know the disease? Results from a cross-sectional survey in Zhejiang, China. *Children (Basel)*. 2022;9(11): 1775. [CrossRef]
6. Thoma VK, Schulz-Zhecheva Y, Oser C, Fleischhaker C, Biscaldi M, Klein C. Media use, sleep quality, and ADHD symptoms in a community sample and a sample of ADHD patients aged 8 to 18 years. *J Atten Disord*. 2020;24(4):576-589. [CrossRef]
7. Mrug S, Molina BS, Hoza B, et al. Peer rejection and friendships in children with attention-deficit/hyperac tivity disorder: contributions to long-term outcomes. *J Abnorm Child Psychol*. 2012;40(6):1013-1026. [CrossRef]
8. Skodzik T, Holling H, Pedersen A. Long-term memory performance in adult ADHD. *J Atten Disord*. 2017;21(4): 267-283.[CrossRef]
9. Wolraich ML, Hagan JF, Allan C, et al. Clinical practice guideline for the diagnosis, evaluation, and treatment of attention-deficit/hyperactivity disorder in children and adolescents. *Pediatrics*. 2019;144(4):e20192528. [CrossRef]
10. Sciberras E, Mulraney M, Hayes N, et al. A brief clinician training program to manage sleep problems in ADHD: what works and what do clinicians and parents think? *Sleep Med*. 2022;89:185-192. [CrossRef]
11. Owens JA. A clinical overview of sleep and attention-deficit/hyperactivity disorder in children and adolescents. *J Can Acad Child Adolesc Psychiatry*. 2009;18(2):92-102. [CrossRef]
12. Sung V, Hiscock H, Sciberras E, Efron D. Sleep problems in children with attention-deficit/hyperactivity disorder: prevalence and the effect on the child and family. *Arch Pediatr Adolesc Med*. 2008;162(4):336-342. [CrossRef]
13. Grünwald J, Schlarb AA. Relationship between subtypes and symptoms of ADHD, insomnia, and nightmares in connection with quality of life in children. *Neuropsychiatr Dis Treat*. 2017;13:2341-2350. [CrossRef]
14. Corkum P, Lingley-Pottie P, Davidson F, et al. Better nights/better days distance intervention for insomnia in school-aged children with/without ADHD: a randomized controlled trial. *J Pediatr Psychol*. 2016;41:701-713. [CrossRef]
15. Stein MA, Weiss M, Hlavaty L. ADHD treatments, sleep, and sleep problems: complex associations. *Neurotherapeutics*. 2012;9(3):509-517. [CrossRef]
16. anzhong Liu H,Zhong Y. Interpretation of the 2018 Canadian society of pediatrics guidelines for the diagnosis and treatment of children and adolescents. *Chin Gen Med*. 2019;22(14):1641. [CrossRef]
17. Zewdie E, Ciechanski P, Kuo HC, et al. Safety and tolerability of transcranial magnetic and direct current stimulation in children: prospective single center evidence from 3.5 million stimulations. *Brain Stimul*. 2020;13(3): 565-575. [CrossRef]
18. Sugaya LS, Salum GA, de Sousa Gurgel W, et al. Efficacy and safety of methylphenidate and behavioural parent training for children aged 3-5 years with attention-deficit hyperactivity disorder: a randomised, double-blind, placebo-controlled, and sham behavioural parent training-controlled trial. *Lancet Child Adolesc Health*. 2022;6(12):845-856. [CrossRef]
19. Rubia K. Neurotherapeutics for ADHD: do they work? *PsyCh J*. 2022;11(3):419-427. [CrossRef]
20. Gao L, Wang C, Song XR, et al. The sensory abnormality mediated partially the efficacy of repetitive transcranial magnetic stimulation on treating comorbid sleep disorder in autism spectrum disorder children. *Front Psychiatry*. 2022;12:820598. [CrossRef]
21. Nagy NAS, Amin GR, Khalil SA, Mahmoud DAM, Elkholy H, Shohdy M. The therapeutic role of repetitive transcranial magnetic stimulation in children with attention deficit/hyperactivity disorder in Egypt a randomized sham controlled clinical trial. *Middle East Curr Psychiatry*. 2022;29(1):55. [CrossRef]
22. Lefaucheur JP, Aleman A, Baeken C, et al. Evidence-based guidelines on the therapeutic use of repetitive transcranial magnetic stimulation (rTMS): an update (2014-2018). *Clin Neurophysiol*. 2020;131(2):474-528. [CrossRef]

23. Ma T, Zhong H. Sleep and sleep disorders in children aged from 0 to 5 years old. *Adv Clin Med*. 2022;12:879-8794. [CrossRef]
24. Jiang B, He D, Guo Z, Mu Q, Zhang L. Efficacy and placebo response of repetitive transcranial magnetic stimulation for primary insomnia. *Sleep Med*. 2019;63:9-13. [CrossRef]
25. Barahona-Corrêa JB, Velosa A, Chainho A, Lopes R, Oliveira-Maia AJ. Repetitive transcranial magnetic stimulation for treatment of autism spectrum disorder: a systematic review and meta-analysis. *Front Integr Neurosci*. 2018;12:27. [CrossRef]
26. Jiang CG, Zhang T, Yue FG, Yi ML, Gao D. Efficacy of repetitive transcranial magnetic stimulation in the treatment of patients with chronic primary insomnia. *Cell Biochem Biophys*. 2013;67(1):169-173. [CrossRef]
27. Guo F, Lou J, Han X, Deng Y, Huang X. Repetitive transcranial magnetic stimulation ameliorates cognitive impairment by enhancing neurogenesis and suppressing apoptosis in the hippocampus in rats with ischemic stroke. *Front Physiol*. 2017;8:559. [CrossRef]
28. Lanza G, Cantone M, Aricò D, et al. Clinical and electrophysiological impact of repetitive low-frequency transcranial magnetic stimulation on the sensorymotor network in patients with restless legs syndrome. *Ther Adv Neurol Disord*. 2018;11:1756286418759973. [CrossRef]
29. Tik M, Hoffmann A, Sladky R. Towards understanding rTMS mechanism of action: stimulation of the DLPFC cause causes network-specifific increase in functional connectivity. *Neuroimage*. 2017;162:189.e96. [CrossRef]
30. Gao L, Wang C, Song XR, et al. The sensory abnormality mediated partially the efficacy of repetitive transcranial magnetic stimulation on treating comorbid sleep disorder in autism spectrum disorder children. *Front Psychiatry*. 2022;12:2544. [CrossRef]
31. Nardone R, Sebastianelli L, Versace V, et al. Effects of repetitive transcranial magnetic stimulation in subjects with sleep disorders. *Sleep Med*. 2020;71:113-121. [CrossRef]
32. Hornstra R, Groenman AP, Van der Oord S, et al. Which components of behavioral parent and teacher training work for children with ADHD?-a metaregression analysis on child behavioral outcomes. *Child Adolesc Ment Health*. 2022. [CrossRef]
33. Arias-Mera C, Paillama-Raimán D, Lucero-González N, Leiva-Bianchi M, Avello-Sáez D. Relation between sleep disorders and attention deficit disorder with hyperactivity in children and adolescents: A systematic review. *Res Dev Disabil*. 2023;137:104500. [CrossRef]