Nonpharmacological Interventions for Attention Deficit Hyperactivity Disorder

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Abstract: Attention Deficit Hyperactivity Disorder (ADHD) is a common cognitive and behavioral disorder in children, marked by age-inappropriate attention deficits, hyperactivity, and/or impulsivity. It brings many negative impacts to patients, families, and society. Drug therapy is widely used, but due to its side effects and the less-than-ideal effectiveness on some comorbidities, non-pharmacological interventions have become a research and clinical hotspot in recent years. This article reviews common domestic non-pharmacological interventions for ADHD and their effectiveness.
***Keywords*:** attention deficit, hyperactivity/impulsivity, children, non-pharmacological intervention, treatment

1. Introduction

Attention Deficit and Hyperactivity Disorder (ADHD), a common childhood neurodevelopmental disorder, is characterized by persistent attention difficulties, overactive behavior, and impulse control problems, which significantly impair children's daily learning, life, and social interaction abilities[1]. In recent years, the incidence of ADHD has shown a significant upward trend, posing great trouble and burden to families and society.

According to the World Health Organization (WHO), the global prevalence of ADHD among children is approximately 7.2%, and about half of the patients continue to be troubled by ADHD symptoms in adulthood, with about 65% of the children possibly suffering from other diseases concurrently[2]. ADHD is a chronic disease that requires long-term treatment. Pharmacotherapy is currently the main method, with commonly used drugs being central nervous system stimulants (methylphenidate) and non-stimulants (atomoxetine), which can significantly improve core ADHD symptoms. However, adverse drug reactions and limitations restrict treatment, with less than 10% of ADHD children persisting in long-term medication. Studies indicate that post-medication ADHD symptoms don't completely disappear but just have baseline improvements, with existing cognitive and social issues, and symptoms often relapse after treatment cessation. ADHD is often accompanied by psychological and behavioral problems, which cannot be effectively resolved by pharmacotherapy alone. Combining non-pharmacological interventions with medication can significantly enhance treatment effectiveness. Non-pharmacological interventions, with their high participation and fun, offer more positive and lasting improvements for patients. The Pediatric Expert Consensus on the Early Identification, Standardized Diagnosis, and Treatment of Attention Deficit Hyperactivity Disorder emphasizes a systematic, individualized approach for ADHD children, recommending non-pharmacological treatment first for those aged 4–6[3]. For school-aged teenagers over 6, though pharmacotherapy is advised, non-pharmacological interventions should still be added to minimize drug dependence and side effects. As ADHD research and treatment practices advance, non-pharmacological therapy is gaining more attention. Provided it's safe and effective, it offers diverse options for ADHD patients. Thus, reviewing non-pharmacological interventions and their efficacy is crucial for guiding ADHD clinical treatment.

2. Psychological and behavioral interventions

Psychological and behavioral interventions are a key part of ADHD non-pharmacological treatment and the most recognized method. They are a first-line treatment, improving cognitive and psychobehavioral symptoms in ADHD children through positive / negative reinforcement.

2.1 Multimodal behavioral intervention

Multimodal Behavioral Intervention is a comprehensive treatment using various behavioral methods to improve ADHD individuals' behavior and psychological state. Parent, school, and peer participation is crucial, as multi-party cooperation enhances behavior and learning outcomes in ADHD children. Current widely-researched and applied methods include Parental Behavior Training (PBT) and school interventions.

2.1.1 Family interventions

Family therapy focuses on systemic adjustments to family interactions and environments, emphasizing collaborative participation to optimize parenting styles and family functioning, thereby alleviating ADHD-related behavioral symptoms. By educating caregivers in behavioral management and improving parent-child communication, these interventions strengthen relationships and enhance children's self-regulation[4]. Studies indicate that ADHD symptom severity correlates with dysfunctional family dynamics, inappropriate parenting styles, and excessive attachment[5]. A case-control study by Moghaddam et al. (ADHD group, n=75; control group, n=75) found that parents of ADHD children exhibited more authoritarian parenting ($M = 23.5$ vs. 20.3, $p<0.001$), with high control and low emotional support linked to increased impulsivity and oppositional behaviors[6]. Additionally, ADHD parents scored significantly lower on permissive parenting (27.4 ± 4.4 vs. 29.0 ± 4.2, $p = 0.019$), suggesting that balanced behavioral control and emotional acceptance may improve self-regulation. These findings highlight family environment optimization as a key target for non-pharmacological ADHD management.

Common family interventions include Behavioral Parent Training (BPT) and Systemic Family Therapy (SFT). BPT utilizes positive reinforcement (rewards) and negative reinforcement (removal of adverse stimuli) to promote desired behaviors, while applying punishments to reduce maladaptive behaviors[7]. SFT emphasizes holistic family system adjustments through interactive sessions, modifying family structures and communication patterns to enhance functionality and alleviate symptoms[8]. Research demonstrates that family interventions significantly reduce hyperactivity, impulsivity, and oppositional behaviors in ADHD children while improving parenting skills and parent-child relationships[8].

2.1.2 School interventions

Schools serve as critical environments for learning and daily life in children with ADHD. Tailored adjustments by teachers and school staff can provide essential support, including behavioral management strategies, classroom rule implementation, reward-punishment systems, and peer support networks. Collaborative efforts between schools and parents to design and execute intervention plans further strengthen outcomes, forming a home-school collaborative intervention system that enhances academic and behavioral progress in children with ADHD[9].

2.2 Cognitive behavioral therapy

Cognitive Behavioral Therapy (CBT), as an evidence-based psychological intervention, systematically modifies cognitive biases and maladaptive behavioral patterns to effectively improve emotional regulation and functional performance. For children with Attention Deficit Hyperactivity Disorder (ADHD), the primary goal of CBT is to enhance executive functioning, specifically targeting attention regulation, inhibition of impulsive behaviors, and improvement of adaptive responses in social contexts. CBT employs techniques such as cognitive restructuring (identifying and adjusting negative thought patterns, training delay strategies in decision-making), behavioral shaping (reinforcing attention-focused exercises, practicing simulated social scenarios), and self-monitoring (using visual feedback tools)[10], collectively strengthening executive functioning and behavioral control in children with ADHD.Research indicates that following CBT treatment, the severity of ADHD symptoms significantly decreases by the end of therapy and remains reduced at 3-and/or 6-month follow-ups ($\Delta CSR = 1.5$, $p<0.001$)[11]. By multidimensionally reshaping cognitive-behavioral patterns, CBT not only alleviates core symptoms but also demonstrates unique advantages in managing comorbidities and enhancing social functioning, underscoring its comprehensive therapeutic value for ADHD.

3. Neuroregulation techniques

3.1 Neurofeedback therapy

Neurofeedback therapy is an emerging treatment that uses EEG to monitor the brain activity of ADHD children, converting brain signals into audiovisual feedback to help them learn to adjust their brainwave patterns and improve cognitive and behavioral performance. Research indicates that EEG in ADHD children typically shows heightened θ waves and reduced β wave activity. Through biofeedback training, θ waves can be decreased and β waves increased, thereby enhancing attention and reducing hyperactivity and impulsivity[12]. Children with ADHD wear EEG monitoring devices and learn to modulate their brainwaves by watching visual or auditory feedback on a computer screen. Stefanie and colleagues conducted a multicenter study involving 142 children with ADHD, assessing the impact of Theta/Beta ratio (TBR) neurofeedback on resting-state and task-related θ activity. The Neurofeedback (NF) group exhibited significant symptom improvement post-treatment and during follow-up[14], with NF effects lasting for months to years.

3.2 Transcranial direct current stimulation

Transcranial Direct Current Stimulation (tDCS) is a novel non-pharmacological approach showing potential in ADHD treatment. It's a non-invasive technique using weak direct currents to modulate neuronal activity in specific brain regions. For ADHD, electrodes are placed on the scalp to deliver weak currents to the prefrontal cortex (especially the dorsolateral prefrontal cortex (dlPFC) and ventromedial prefrontal cortex (vmPFC)), areas crucial for executive function and attention control. Anodal stimulation of the dlPFC boosts neuronal activity and regulates subcortical dopamine levels, while cathodal stimulation has the opposite effect. This electrical stimulation can enhance attention, inhibitory control, and working memory in children with ADHD[14]. Salehinejad et al.'s research shows tDCS significantly impacts executive function, with right-hemisphere tDCS more significantly improving executive function accuracy and left-hemisphere tDCS showing significant effects on inhibitory control[15,16]. Moreover, tDCS can increase dlPFC activity. In Allenby et al.'s study, the tDCS group showed a significant reduction in impulsivity on the Conners' Continuous Performance Test (CPT) at treatment end (β=-0.36, 95% CI: -0.54~-0.18, $p<0.001$), indicating tDCS is effective in reducing impulsivity in ADHD patients[17].

3.3 Transcranial magnetic stimulation

Transcranial Magnetic Stimulation (TMS) is a non-invasive neuroregulation technique that uses high-frequency alternating magnetic fields to induce currents in target brain regions (such as the dorsolateral prefrontal cortex, dlPFC), modulating neuronal excitability and synaptic plasticity. In ADHD treatment, repetitive TMS (rTMS) targets the executive function network via frequency-dependent mechanisms, primarily acting on the dlPFC. Low-frequency rTMS inhibits excessive activation in the right dlPFC and supplementary motor area (SMA), reducing abnormal cortical-striatal circuit excitability and alleviating hyperactivity and impulsivity. High-frequency rTMS enhances functional segregation between the left dlPFC and the default mode network (DMN), improving attention. In a study[18], Nakajima et al. found that applying low-frequency TMS to the left dlPFC and high-frequency TMS to the right in children with left-dlPFC dysfunction reduced their diagnostic scores by about 50% compared to controls, and eased anxiety and depression. This highlights TMS's potential in modulating brain activity and improving ADHD symptoms.

4. Exercise therapy

Exercise therapy, including sensory integration, balance, and sports training, uses organized physical activities to enhance coordination, attention, and overall fitness in ADHD children, addressing physiological and psychological issues.

4.1 Sensory integration training

Sensory Integration Therapy (SIT) is a neurodevelopmental-theory-based behavioral intervention. It uses structured sensory inputs (tactile, vestibular, proprioceptive, etc.) to boost the brain's multimodal information integration, improving Sensory Processing Disorder (SPD) and related behaviors[19]. 40%-70% of ADHD children have sensory integration dysfunction, shown as hypersensitivity or hyposensitivity to stimuli, leading to attention deficits, hyperactivity, and impulsivity[20]. Studies show SIT helps children adapt to sensory stimuli in a safe environment, regulate responses, enhance attention, reduce hyperactivity, and improve social skills. However, children of different ages respond differently to SIT, necessitating individualized training plans[21].

4.2 Aerobic exercise

Aerobic Exercise is sustained, rhythmic whole-body movement (e.g., running, swimming, cycling) done in well-oxygenated conditions, raising heart rate and oxygen consumption. Davis et al. confirmed aerobic exercise improves executive function (inhibitory control, working memory, cognitive flexibility) in ADHD children[22]. Intention-to-treat analysis showed a significant effect on executive function (β = 0.36, 95% CI: 0.6-4.8, p = 0.013). Moderate/high intensity aerobic exercise triggers neurophysiological responses, stimulating neurotransmitter production and brain-derived neurotrophic factor (BDNF) release, and boosting cerebral blood flow[23]. This enhances neural adaptability and information processing, alleviating ADHD symptoms and complications, promoting brain development, and inducing structural and functional brain changes. These changes strengthen neuroplasticity, laying the foundation for cognitive improvement[24].

4.3 Yoga and Tai Chi

Yoga and Tai Chi combine body movements, breathing, and meditation. Their slow, rhythmic actions require focus and coordination, helping ADHD children enhance attention and self-awareness[25]. Deep breathing and meditation teach children to relax, reducing anxiety and improving emotional regulation. Long-term practice significantly improves attention span, impulse control, and social skills in ADHD children[26,27].

5. Dietary adjustments

ADHD arises from gene-environment interaction, with diet being a key environmental factor. Common dietary interventions include the DASH diet, artificial food colorant (AFC) elimination, and polyunsaturated fatty acid (PUFA) supplementation. One study[28] showed the DASH diet group had a greater Conner's score change than the control ($P<0.05$), yet no significant difference based on the SNAP-IV scale. Teacher reports indicated more improvements in emotional symptoms, behavior, peer relationships, and prosocial behavior in the DASH group ($P<0.05$).

Scientific research suggests a link between ADHD risk in children and consumption of foods with artificial colors and preservatives. However, the UK NICE guidelines don't recommend AFC elimination as a routine intervention, as it may only benefit children sensitive to AFC[29].

PUFA, a key component of nerve cell membranes, regulates membrane fluidity and nerve conduction. PUFA deficiency can harm nerve cells and disrupt neurotransmitter secretion and release, such as dopamine and serotonin. Some studies[30] find a link between PUFA levels and ADHD symptoms, with lower PUFA levels in ADHD children. Omega-3 fatty acid supplementation can alleviate ADHD symptoms, particularly in improving attention and reducing hyperactivity. High-quality evidence shows no significant effect of omega-3 PUFA on core ADHD symptoms (SMD: 0.08~0.09), while low-quality studies suggest a possible synergistic effect when combined with stimulants (RR 1.95). Some research indicates omega-3 PUFA may improve ADHD symptoms in the medium term, but high-quality evidence finds no significant impact on parent-rated overall ADHD symptoms, inattention, and hyperactivity / impulsivity scores.

6. Sleep intervention

Studies indicate that up to 70% of ADHD children have sleep problems, which not only affect nighttime rest but also worsen daytime ADHD symptoms like inattention, mood swings, and behavioral issues, creating a vicious cycle. Sleep intervention mainly consists of sleep hygiene education and relaxation training: teaching children and parents good sleep hygiene and pre-sleep relaxation techniques, maintaining a regular sleep schedule, and reducing pre-sleep anxiety. study shows[31] that after behavioral sleep intervention, at 12-month follow-up, the intervention group had significant improvements in sleep problems, ADHD symptom severity, quality of life, daily functioning, and behavior (95% CI:-5.4~-1.4, $P < 0.001$). Other studies also find that sleep intervention can improve sleep architecture and quality in ADHD children, increasing deep and REM sleep time, thus boosting daytime attention and executive function[32].

7. Others

Music therapy utilizes sound and rhythm as therapeutic tools. Studies suggest that music influences multiple brain regions involved in emotional regulation, stress response, and cognitive function. By stimulating multisensory pathways, music therapy may increase serotonin (5-HT) secretion, reduce cortisol levels, and thereby improve attention, mood, and stress reduction in ADHD patients[33].

ADHD digital therapy, a software-based intervention, leverages brain plasticity to improve brain function through cognitive training, targeting core ADHD symptoms like attention and behavioral control.

Fecal microbiota transplantation (FMT) is an emerging treatment showing great potential in ADHD management. Recent studies reveal that 40%-70% of ADHD children have gut microbiota dysbiosis, which may lead to sensory over-sensitivity or dullness, causing attention deficits, hyperactivity, and impulsivity. This dysbiosis can disrupt the gut-brain axis, affecting neurotransmitter levels and potentially influencing ADHD development[34]. However, this viewpoint needs further research.

8. Traditional Chinese Medicine therapies

Acupuncture and tuina are two non-pharmacological therapies widely utilized in Traditional Chinese Medicine (TCM). The combination of acupuncture and tuina may regulate visceral yin-yang balance, stimulate cerebral cortex activity, and improve psychological and behavioral issues in children with ADHD by promoting neural fiber growth and development, as well as modulating cortical activity[35,36].

9. Conclusion

For preschoolers or mild -to -moderate ADHD patients, non-pharmacological interventions are widely recognized and preferred. They not only complement pharmacological treatments, enhancing cognitive, behavioral, and social functioning, but also help reduce drug doses and side effects. As medical technology advances, non-pharmacological interventions are constantly innovating, offering more diverse ADHD treatment options. However, to better meet the needs of different ADHD

subtypes, further research is needed on individualized treatment plans, mechanisms, and long-term effects to ensure scientific and effective treatment.

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