

运动即良药：基于 fNIRS 的太极拳改善戒毒者身心健康的证据

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摘要：毒品滥用已成为全球性公共卫生危机，因吸毒导致执行功能（抑制、刷新、转换）与工作记忆的显著衰退，成为复吸的核心诱因。研究表明，甲基苯丙胺、海洛因等成瘾者前额叶氧合血红蛋白（HbO）浓度异常波动与认知控制损伤高度相关。传统运动干预（如太极拳、有氧运动）虽能改善认知功能，但其效果评估多依赖主观问卷或行为任务（Stroop、N-back），缺乏相对科学及客观的检测手段。此外，现有戒毒康复研究对脑功能动态变化的监测不足，亟需引入便携式功能性近红外光谱成像（fNIRS）技术以揭示运动干预的神经适应性过程。研究背景基于“运动即良药”的理念，旨在通过科学方法验证太极拳在改善认知功能、脑血氧水平及心理健康方面的独特优势。研究选取 42 名男性戒毒人员，随机分为太极拳组、有氧运动组和常规对照组，进行为期 12 周、每周 3 次、每次 60 分钟的干预。太极拳组练习太极健心操与康复操，有氧组进行跑步机或单车训练，对照组维持常规戒断治疗。研究采用 fNIRS 技术监测前额叶皮层的氧合血红蛋白（HbO₂）变化，评估静息态与运动态下的脑功能，并结合 Stroop 与 3-Back 任务测试认知功能。结果显示，太极拳组在认知功能改善和脑功能连接增强方面表现尤为突出。干预后，太极组前额叶多个脑区的功能连接显著增强，特别是背外侧与腹外侧前额叶之间的正向连接明显提升，且该组在认知任务中的反应时与脑区激活呈现广泛相关性，优于有氧组和对照组。组间比较表明，太极拳在促进大脑功能整合方面显著优于有氧运动（ $p = 0.004$ ），尤其在左侧背外侧前额叶的激活效应更强。总而言之，运动对戒毒康复具有积极意义，而太极拳因其身心协同调节的特点，在认知修复和神经功能改善方面展现出独特优势，适合作为戒毒康复的特色干预手段。同时，研究倡导在康复过程中引入 fNIRS 等多元评估技术，实现精准监测与科学评价。该成果为“运动处方”在特殊人群健康干预中的应用提供了有力证据。

关键词：太极拳；认知功能；近红外；前额叶皮层；药物依赖

Exercise is a Medicine: Tai Chi Improves the Physical and Mental Health of Recovery for Substance Use Disorder -Evidence from

fNIRS

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Abstract: Substance Use Disorder (SUD) has become a global public health problem. The significant decline in executive functions (inhibition, refreshing, and switching) and working memory caused by drug use is a main factor causing to relapse. Studies have shown that the abnormal fluctuations in the concentration of oxygenated hemoglobin (HbO) in the prefrontal cortex of methamphetamine and heroin dependents are highly correlated with cognitive control impairment. Although traditional exercise interventions (such as Tai Chi and aerobic exercise) can improve cognitive function, their effects are often evaluated through questionnaires or behavioral tasks (Stroop, N-back), lacking relatively strong evidence to prove it. Moreover, there are lack of sufficient evidence collecting the dynamic changes in brain function in SUD rehabilitation research, it is required to introduce a portable functional near-infrared spectroscopy (fNIRS) technology to reveal the neuroadaptive processes of exercise intervention. Based on the concept of "exercise is medicine," this study aimed to verify the unique advantages of Tai Chi in improving cognitive function, brain blood oxygen levels, and mental health. The study selected 42 male SUD subjects and randomly allocated into a Tai Chi group, an aerobic exercise group, and a conventional control group. They underwent 12 weeks of intervention, three times a week, for 60 minutes each time. The Tai Chi group practiced Tai Chi for Mind-body exercise and Tai Chi, the aerobic group performed treadmill or cycling training, and the control group received the conventional educational treatment. fNIRS was used to detect the changes in oxygenated hemoglobin (HbO₂) in the prefrontal cortex, assessing brain function in both resting and active states, and combined with Stroop and 3-Back tasks to test cognitive function. The results showed that the Tai Chi group performed particularly well in improving cognitive function and enhancing brain functional connectivity. After the intervention, the functional connectivity in multiple brain regions of the prefrontal cortex in the Tai Chi group significantly increased, especially the positive connection between the dorsolateral and ventrolateral prefrontal cortex. Moreover, the reaction time and brain region activation in cognitive tasks in this group were widely correlated, outperforming the aerobic group and the control group. Within-group comparisons indicated that Tai Chi was significantly

more effective than aerobic exercise in promoting brain function integration ($p = 0.004$), especially in the activation effect of the left dorsolateral prefrontal cortex. In conclusion, exercise has a positive impact on SUD rehabilitation, and Tai Chi, with its characteristic of coordinating physical and mental regulation, shows unique advantages in cognitive repair and neural function improvement, making it a suitable intervention method for SUD rehabilitation. At the same time, the study advocates the introduction of multiple assessment techniques such as fNIRS in the rehabilitation process to achieve precise monitoring and scientific evaluation. This achievement provides strong evidence for the application of "exercise prescriptions" in health interventions for special populations.

Keywords: Tai Chi; cognitive function; near-infrared; prefrontal cortex; Substance Use Disorder

