太极拳改善睡眠的神经生物学机制探讨

胡泽林，张靓

北京师范大学，北京　100875

摘要：研究目的：睡眠是维持人体健康与中枢神经系统正常功能不可或缺的重要生理过程，其中慢波睡眠（slow wave sleep, SWS）在能量代谢、突触稳态调节和长期记忆巩固中起到关键作用。近年来，肥胖与高血压人群比例持续攀升，这类人群常伴随不同程度的睡眠障碍，如入睡困难、夜间易醒、深度睡眠不足等。睡眠障碍不仅显著降低生活质量，更与认知功能衰退、情绪问题以及心脑血管疾病风险上升密切相关。因此，探索安全有效的非药物干预策略以改善睡眠，已成为当前公共卫生领域的一项重要课题。太极拳作为中国传统的代表性身心锻炼方式，强调呼吸调节、意念专注与动作舒缓协调，具有悠久的临床应用历史。大量研究显示，长期坚持太极拳练习可改善睡眠质量，缓解焦虑与抑郁状态，并提升整体健康水平。然而，现有研究多集中于效果观察，对其背后的神经生物学机制尚缺乏系统性的梳理与深入探讨。本研究旨在综述太极拳改善睡眠质量的潜在神经生物学机制，分别从神经递质调节、代谢信号改变、脑功能可塑性以及自主神经调控等多个方面进行系统分析，以期为后续实验研究及临床实践提供理论依据。**研究方法：**本研究采用文献综述的方法，系统梳理了过去十余年国内外的相关研究成果。通过检索 PubMed、Web of Science 及中国知网（CNKI），以太极拳、睡眠、慢波睡眠、神经递质、代谢信号等为关键词，筛选以临床观察、基础实验及机制探讨为主的文献，重点关注与睡眠相关的神经递质变化、脑区活动及自主神经功能指标。**研究结果：**文献综述结果显示，太极拳对睡眠的改善作用可能通过多层次的生理机制共同实现。首先，在神经递质调节方面，太极拳作为一种融合身心协调的运动方式，在调节神经递质水平方面展现出潜在的作用。例如，一项针对帕金森病患者的研究表明，长期太极拳训练可提升脑源性神经营养因子（BDNF）水平，并降低炎症因子 eotaxin 的表达，这些变化与患者认知功能的改善密切相关，而认知改善往往伴随睡眠质量的提升。此外，也有研究发现太极拳能够提高血清 5-羟色胺（5-HT）水平，可能通过调节情绪状态与昼夜节律，间接促进睡眠优化。在代谢层面，太极拳可通过调节能量代谢与免疫代谢通路，为睡眠的生理基础提供支持。在帕金森患者的代谢组学研究中，太极拳干预显著改善了三羧酸循环（TCA）、脂肪酸β氧化及氨基酸代谢等关键路径，这些代谢变化有助于减轻中枢神经系统的氧化应激和炎症反应，从而为睡眠创造更稳定的内环境。另有研究提出，乳酸

作为运动代谢产物，可能也在脑功能调节和神经递质释放中发挥作用，太极拳或通过适度调控乳酸水平优化神经代谢环境，但该机制尚需更多直接证据支持。在大脑可塑性方面，神经影像学研究提示，长期太极拳训练可诱发大脑结构与功能的重组，包括增强默认模式网络（DMN）与执行控制网络（ECN）的功能连接。这些网络与情绪调控、认知功能及睡眠维持密切相关。此外，太极拳练习还可增加前额叶等关键脑区的灰质体积和神经活动，有助于减少夜间觉醒、提升深睡眠比例。最后，在自主神经调节方面，太极拳凭借其缓慢节律、配合深长呼吸的动作特点，可有效调节自主神经平衡。多项研究证实，太极拳能够提高心率变异性（HRV），增强副交感神经活性，从而促进入睡并维持睡眠连续性。在老年人群中的研究还发现，太极拳可改善心肺耦合（CPC）指数，进一步证实其在提升睡眠稳定性方面的生理作用。**研究结论：**从现有研究可以看出，太极拳在改善睡眠方面的作用是多层次的，它既涉及神经递质和代谢的调节，也与大脑功能的可塑性和自主神经的平衡密切相关。这些变化共同作用，使睡眠环境更为稳定，深睡眠得以维持。虽然目前的研究还不足以完全揭示其中的机制，但已有的证据已经展现出太极拳在睡眠健康中的潜在价值，也提示这一传统运动方式在未来值得更深入的探讨。

关键词：太极拳；睡眠；慢波睡眠

Exploring the neurobiological mechanisms of Tai Chi in improving sleep

Zelin Hu, Jing Zhang

Beijing Normal University, Beijing 100875

Abstract: Research Objective: Sleep is an essential physiological process for maintaining human health and normal functioning of the central nervous system. Among its various stages, slow wave sleep (SWS) plays a pivotal role in energy metabolism, synaptic homeostasis, and long-term memory consolidation. In recent years, the prevalence of obesity and hypertension has continued to rise, and these conditions are frequently accompanied by sleep disturbances such as difficulty initiating sleep, frequent nocturnal awakenings, and insufficient deep sleep. Such disturbances not only reduce quality of life but are also strongly associated with cognitive decline, emotional disorders, and increased risk of cardiovascular and cerebrovascular diseases. Consequently, identifying safe and effective non-pharmacological interventions to improve sleep has become an important public health priority. Tai Chi, a traditional Chinese mind–body practice, emphasizes breath regulation, mental focus, and slow, coordinated movements, and has a long

history of clinical application. Numerous studies have demonstrated that regular Tai Chi practice can improve sleep quality, alleviate anxiety and depression, and enhance overall health. However, existing research has largely focused on outcome evaluation, with relatively limited attention given to its underlying neurobiological mechanisms. This study aims to review the potential neurobiological mechanisms by which Tai Chi improves sleep quality, focusing on neurotransmitter regulation, metabolic signaling, brain functional plasticity, and autonomic nervous system modulation, in order to provide a theoretical basis for future experimental studies and clinical applications. **Research Methods:** This study adopts a literature review approach to systematically summarize research findings from the past decade both in China and abroad. Relevant publications were retrieved from PubMed, Web of Science, and CNKI using the keywords “Tai Chi,” “sleep,” “slow wave sleep,” “neurotransmitters,” and “metabolic signaling.” The selection focused primarily on studies of clinical observations, basic experiments, and mechanistic explorations, with particular attention to changes in sleep-related neurotransmitters, brain activity patterns, and autonomic nervous system function. **Research Results:** The review indicates that the beneficial effects of Tai Chi on sleep may be achieved through multiple physiological pathways. First, in terms of neurotransmitter regulation, Tai Chi, as a mind–body integrative exercise, shows potential in modulating neurotransmitter levels. For instance, a study in patients with Parkinson’s disease reported that long-term Tai Chi practice increased brain-derived neurotrophic factor (BDNF) levels while reducing the expression of the inflammatory factor eotaxin. These changes were closely associated with improvements in cognitive function, which are often accompanied by better sleep quality. In addition, other studies have found that Tai Chi can elevate serum serotonin (5-HT) levels, potentially optimizing sleep indirectly by modulating emotional states and circadian rhythms. At the metabolic level, Tai Chi may support the physiological foundation of sleep by influencing energy and immune metabolic pathways. Metabolomic studies in Parkinson’s patients revealed that Tai Chi significantly improved the tricarboxylic acid (TCA) cycle, fatty acid β-oxidation, and amino acid metabolism. Such metabolic adaptations help to reduce oxidative stress and neuroinflammation, thereby providing a more stable internal environment for sleep. Some studies also suggest that lactate, a byproduct of exercise metabolism, may contribute to brain function regulation and neurotransmitter release. Tai Chi may help modulate lactate levels to optimize the neuro-metabolic environment, though more direct evidence is needed to confirm this mechanism. With respect to brain plasticity, neuroimaging studies suggest that long-term Tai Chi training can induce structural and

functional reorganization of the brain, including enhanced connectivity within the default mode network (DMN) and executive control network (ECN), both of which are strongly linked to emotion regulation, cognitive function, and sleep maintenance. Tai Chi practice has also been associated with increased gray matter volume and neural activity in key regions such as the prefrontal cortex, which may contribute to reduced nocturnal awakenings and greater proportions of deep sleep. Finally, in terms of autonomic regulation, the slow and rhythmic movements of Tai Chi, combined with deep breathing, appear to effectively improve autonomic balance. Multiple studies have confirmed that Tai Chi can increase heart rate variability (HRV) and enhance parasympathetic activity, thereby facilitating sleep onset and continuity. Research in older adults has further shown that Tai Chi improves the cardiopulmonary coupling (CPC) index, providing additional support for its role in stabilizing sleep physiology. **Research Conclusion:** Current evidence suggests that the effects of Tai Chi on sleep are multi-dimensional, involving the regulation of neurotransmitters and metabolic processes, as well as changes in brain plasticity and autonomic balance. These adaptations act together to create a more stable physiological environment that supports the maintenance of deep sleep. Although existing studies are not yet sufficient to fully clarify the underlying mechanisms, the available findings highlight the potential value of Tai Chi in promoting sleep health and indicate that this traditional practice merits further in-depth investigation.

Keywords: Tai Chi; Sleep; Slow Wave Sleep