

- with cardiometabolic health [J]. *Am J Respir Crit Care Med*, 2022, 205 (10): 1202-1213. DOI: 10.1164/rccm.202104-0971OC.
- [9] CHRISTIAN L M, CARROLL J E, TETI D M, et al. Maternal sleep in pregnancy and postpartum part I: mental, physical, and interpersonal consequences [J]. *Curr Psychiatry Rep*, 2019, 21 (3): 20. DOI: 10.1007/s11920-019-0999-y.
- [10] NAKAHARA K, MICHIKAWA T, MOROKUMA S, et al. Association of maternal sleep before and during pregnancy with sleep and developmental problems in 1-year-old infants [J]. *Sci Rep*, 2021, 11 (1): 11834. DOI: 10.1038/s41598-021-91271-7.
- [11] 何权瀛, 刘国莉. 妊娠期阻塞性睡眠呼吸暂停低通气综合征临床诊治专家共识(草案) [J]. *中国呼吸与危重监护杂志*, 2018, 17 (5): 439-444.  
HE Q Y, LIU G L. Expert consensus on diagnosis and management of obstructive sleep apnea hypopnea syndrome during pregnancy (draft) [J]. *Chin J Respir Crit Care Med*, 2018, 17 (5): 439-444.
- [12] 中国儿童OSA诊断与治疗指南制订工作组, 中华医学会耳鼻咽喉头颈外科学分会小儿学组, 中华医学会儿科学分会呼吸学组, 等. 中国儿童阻塞性睡眠呼吸暂停诊断与治疗指南(2020) [J]. *中华耳鼻咽喉头颈外科杂志*, 2020, 55 (8): 729-747. DOI: 10.3760/cma.j.cn115330-20200521-00431.  
The Working Group on the Development of Chinese Guidelines for the Diagnosis and Treatment of Pediatric OSA, the Pediatric Group of the Chinese Medical Association's Otorhinolaryngology-Head and Neck Surgery Branch, the Respiratory Group of the Chinese Medical Association's Pediatrics Branch. et al. Chinese guideline for the diagnosis and treatment of childhood obstructive sleep apnea (2020) [J]. *Chin J Otorhinolaryngol Head Neck Surg*, 2020, 55 (8): 729-747. DOI: 10.3760/cma.j.cn115330-20200521-00431.
- [13] SELIM B, RAMAR K. Sleep-related breathing disorders: when CPAP is not enough [J]. *Neurotherapeutics*, 2021, 18 (1): 81-90. DOI: 10.1007/s13311-020-00955-x.
- [14] GUILLEMINAULT C, KREUTZER M, CHANG J L. Pregnancy, sleep disordered breathing and treatment with nasal continuous positive airway pressure [J]. *Sleep Med*, 2004, 5 (1): 43-51. DOI: 10.1016/j.sleep.2003.07.001.
- [15] RICE A L, BAJAJ S, WIEDMER A M, et al. Continuous positive airway pressure treatment of obstructive sleep apnea and hypertensive complications in high-risk pregnancy [J]. *Sleep Breath*, 2023, 27 (2): 621-629. DOI: 10.1007/s11325-022-02669-0.
- [16] FACCO F L, WOLSK J, PATEL S R, et al. A trial of positive airway pressure for the treatment of sleep apnea in pregnancy [J]. *Am J Obstet Gynecol MFM*, 2023, 5 (3): 100840. DOI: 10.1016/j.ajogmf.2022.100840.
- [17] 杨学杰. 睡眠呼吸暂停综合征合并妊娠期高血压疾病患者的母婴结局及持续气道正压通气的干预效果 [J]. *中国妇幼保健*, 2018, 33 (24): 5729-5731. DOI: 10.7620/zgfybj.j.issn.1001-4411.2018.24.20.
- YANG X J. Maternal and infant outcomes of patients with sleep apnea syndrome combined with hypertensive disease during pregnancy and the intervention effect of continuous positive airway pressure [J]. *Matern Child Health Care China*, 2018, 33 (24): 5729-5731. DOI: 10.7620/zgfybj.j.issn.1001-4411.2018.24.20.
- [18] 黄国晓. 经鼻持续正压通气治疗妊娠合并中重度阻塞性睡眠呼吸暂停低通气综合征对患者血气指标的影响 [J/OL]. *现代医学与健康研究(电子版)*, 2022, 6 (19): 73-76.  
HUANG G X. Effect of nasal continuous positive airway pressure on blood gas indicators in patients with pregnancy-associated moderate to severe obstructive sleep apnea hypopnea syndrome [J/OL]. *Mod Med Health Res Electron J*, 2022, 6 (19): 73-76.
- [19] STAJIĆ D, ILIĆ D, VUKOVIĆ J, et al. The effect of continuous positive airway pressure treatment on hypertensive disorder in pregnant women with obstructive sleep apnea [J]. *Sleep Breath*, 2022, 26 (1): 297-305. DOI: 10.1007/s11325-021-02397-x.
- [20] EDWARDS N, BLYTON D, KIRJAVAINEN T, et al. Nasal continuous positive airway pressure reduces sleep-induced blood pressure increments in preeclampsia [J]. *Am J Respir Crit Care Med*, 2000, 162 (1): 252-257. DOI: 10.1164/ajrccm.162.1.9905006.
- [21] GUILLEMINAULT C, PALOMBINI L, POYARES D, et al. Preeclampsia and nasal CPAP: part 1. early intervention with nasal CPAP in pregnant women with risk-factors for pre-eclampsia: preliminary findings [J]. *Sleep Med*, 2007, 9 (1): 9-14. DOI: 10.1016/j.sleep.2007.04.020.
- [22] POYARES D, GUILLEMINAULT C, HACHUL H, et al. Preeclampsia and nasal CPAP: part 2. hypertension during pregnancy, chronic snoring, and early nasal CPAP intervention [J]. *Sleep Med*, 2007, 9 (1): 15-21. DOI: 10.1016/j.sleep.2007.04.019.
- [23] TANTRAKUL V, INGSATHIT A, LIAMSOMBUT S, et al. Treatment of obstructive sleep apnea in high risk pregnancy: a multicenter randomized controlled trial [J]. *Respir Res*, 2023, 24 (1): 171. DOI: 10.1186/s12931-023-02445-y.
- [24] REID J, TAYLOR-GJEVRE R, GJEVRE J, et al. Can gestational hypertension be modified by treating nocturnal airflow limitation [J]. *J Clin Sleep Med*, 2013, 9 (4): 311-317. DOI: 10.5664/jcsm.2574.
- [25] REUTRAKUL S, MOKHLESI B. Obstructive sleep apnea and diabetes A state of the art review [J]. *Chest*, 2017, 152 (5): 1070-1086. DOI: 10.1016/j.chest.2017.05.009.
- [26] WANITCHAROENKUL E, CHIRAKALWASAN N, AMNAKITTIKUL S, et al. Obstructive sleep apnea and diet-controlled gestational diabetes [J]. *Sleep Med*, 2017, 39: 101-107. DOI: 10.1016/j.sleep.2017.08.010.
- [27] STREET L M, ASCHENBRENNER C A, HOULE T T, et al. Gestational obstructive sleep apnea; biomarker screening models and lack of postpartum resolution [J]. *J Clin Sleep Med*, 2018, 14 (4): 549-555. DOI: 10.5664/jcsm.7042.
- [28] TOMKIEWICZ J, DARMOCHWAŁ-KOLARZ D A. Biomarkers for early prediction and management of preeclampsia: a comprehensive review [J]. *Med Sci Monit*, 2024, 30: e944104. DOI: 10.12659/MSM.944104.

- [29] 卞海艳, 刘照龙, 胡小梅, 等. 经鼻持续正压通气治疗妊娠期 OSAHS 及对患者血清 AOPP、MIF、IL-18 影响 [J]. 中国计划生育学杂志, 2019, 27 (12): 1648-1651. DOI: 10.3969/j.issn.1004-8189.2019.12.019.
- BIAN H Y, LIU Z L, HU X M, et al. Influence of continuous positive airway through the nose for treating pregnant women with OSAHS on serum AOPP, MIF and IL-18 [J]. Chin J Fam Plan, 2019, 27 (12): 1648-1651. DOI: 10.3969/j.issn.1004-8189.2019.12.019.
- [30] 吴寒晴, 钱炜, 陈芳, 等. 妊娠合并阻塞性睡眠呼吸暂停患者血压、血糖、炎性细胞因子变化及临床意义 [J]. 医学研究杂志, 2023, 52 (3): 160-164, 193. DOI: 10.11969/j.issn.1673-548X.2023.03.033.
- WU H Q, QIAN W, CHEN F, et al. Changes and clinical significance of blood pressure, blood glucose and inflammatory factors in pregnancy with obstructive sleep apnea [J]. J Med Res, 2023, 52 (3): 160-164, 193. DOI: 10.11969/j.issn.1673-548X.2023.03.033.
- [31] 李姗姗, 李晶晶, 莫星帆, 等. IL-6 在光动力疗法应用中的研究进展 [J]. 新医学, 2023, 54 (10): 695-699. DOI: 10.3969/j.issn.0253-9802.2023.10.001.
- LI S S, LI J J, MO X F, et al. Research progress in the application of IL-6 in photodynamic therapy [J]. J New Med, 2023, 54 (10): 695-699. DOI: 10.3969/j.issn.0253-9802.2023.10.001.
- [32] 刘彬, 薛林, 赵辉明, 等. CPAP 对 HDCP 合并 OSAHS 患者母婴结局、炎性标志物及血压的影响 [J]. 中国妇幼保健, 2019, 34 (11): 2453-2456. DOI: 10.7620/zgfybj.j.issn.1001-4411.2019.11.11.
- LIU B, XUE L, ZHAO H M, et al. Effect of CPAP on maternal and infant outcomes, inflammatory markers and blood pressure in patients with HDCP complicated with OSAHS [J]. Matern Child Health Care China, 2019, 34 (11): 2453-2456. DOI: 10.7620/zgfybj.j.issn.1001-4411.2019.11.11.
- [33] 王淑民. CPAP 对妊高征合并 OSAHS 患者炎症因子平均动脉压的影响 [J]. 河北医学, 2017, 23 (7): 1177-1180. DOI: 10.3969/j.issn.1006-6233.2017.07.035.
- WANG S M. Effect of CPAP on the mean arterial pressure of inflammatory factors in patients with pregnancy-induced hypertension complicated with OSAHS [J]. Hebei Med, 2017, 23 (7): 1177-1180. DOI: 10.3969/j.issn.1006-6233.2017.07.035.
- [34] 王坤, 张吉仲, 李静, 等. 妊娠高血压合并 OSAHS 患者应用 CPAP 治疗对母儿结果的影响 [J]. 临床耳鼻咽喉头颈外科杂志, 2017, 31 (4): 293-296. DOI: 10.13201/j.issn.1001-1781.2017.04.011.
- WANG K, ZHANG J Z, LI J, et al. Maternal-infant outcome of patients with OSAHS & gestational hypertension treated by CPAP [J]. J Clin Otorhinolaryngol Head Neck Surg, 2017, 31 (4): 293-296. DOI: 10.13201/j.issn.1001-1781.2017.04.011.
- [35] BLYTON D M, SULLIVAN C E, EDWARDS N. Reduced nocturnal cardiac output associated with preeclampsia is minimized with the use of nocturnal nasal CPAP [J]. Sleep, 2004, 27 (1): 79-84. DOI: 10.1093/sleep/27.1.79.
- [36] BLYTON D M, SKILTON M R, EDWARDS N, et al. Treatment of sleep disordered breathing reverses low fetal activity levels in preeclampsia [J]. Sleep, 2013, 36 (1): 15-21. DOI: 10.5665/sleep.2292.
- [37] 谷亮, 吴波. 持续气道正压通气治疗依从性对妊娠合并阻塞性睡眠呼吸暂停低通气综合征患者妊娠结局的影响 [J]. 临床内科杂志, 2021, 38 (8): 522-525. DOI: 10.3969/j.issn.1001-9057.2021.08.006.
- GU L, WU B. Influence of compliance of continuous positive airway pressure treatment on pregnancy outcome of pregnant patients with obstructive sleep apnea-hypopnea syndrome [J]. J Clin Intern Med, 2021, 38 (8): 522-525. DOI: 10.3969/j.issn.1001-9057.2021.08.006.
- [38] PATIL S P, AYAPPA I A, CAPLES S M, et al. Treatment of adult obstructive sleep apnea with positive airway pressure: an American academy of sleep medicine systematic review, meta-analysis, and GRADE assessment [J]. J Clin Sleep Med, 2019, 15 (2): 301-334. DOI: 10.5664/jcsm.7638.

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## · 睡眠医学 · 综述 ·

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## 气候要素影响睡眠质量的作用机制

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**【摘要】** 睡眠是人类维持生命活动的基本需求, 睡眠质量与人体健康密切相关。随着全球气候的急剧变化, 越来越多的研究发现气候变化对人类的睡眠质量产生了重要的影响, 且这种影响是一个多因素交互作用的复杂过程, 气候要素通过影响人体生理以及睡眠环境的舒适性, 进而影响个体的睡眠质量。文章综述国内外关于温度、湿度、气压、氧含量及光照等气候要素影响睡眠质量的研究, 分析气候变化中不同影响因素对睡眠质量的作用机制, 旨在为临床上治疗睡眠障碍提供参考。

**【关键词】** 气候要素; 睡眠质量; 睡眠障碍; 影响因素; 作用机制

## Review of the mechanisms of climatic elements on sleep quality

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**【Abstract】** Sleep is a basic need for human life-sustaining activities, and sleep quality is closely related to human health. With the rapid changes in the global climate, an increasing number of studies have found that climate change has an important impact on sleep quality of human beings, and this impact is a complex process involving multiple interacting factors. Climate factors affect human physiology and the comfort of the sleep environment, which then affects the sleep quality of individuals. This article reviews domestic and international studies on the effects of climate factors such as temperature, humidity, air pressure, oxygen content and light on sleep quality, and analyse the mechanism of climate change on sleep quality, with the purpose of providing reference for the clinical treatment of sleep disorders.

**【Key words】** Climate elements; Sleep quality; Sleep disorders; Influencing factors; Mechanism

睡眠是人类维持生命活动的基本需求, 对维系人类的身心健康十分重要<sup>[1]</sup>。睡眠障碍是指睡眠量不正常以及睡眠中出现异常行为的表现, 其包含了多种睡眠疾病, 其中失眠障碍是最常见的类型之一。我国自评存在睡眠质量问题的居民比例为10.40%, 且呈逐年上升趋势<sup>[2]</sup>。存在睡眠问题的人群遍布各个年龄段, 包括儿童、青年、中年和老年, 睡眠问题已经逐步演变成一个无法忽视的健康焦点问题<sup>[3]</sup>。值得注意的是, 近几年来气候变化对睡眠质量的影响在国内外学术研究领域引起了广泛的关注与讨论, 气候环境的变化在一定程度上影响

着人体内的昼夜节律系统<sup>[4]</sup>和神经内分泌系统<sup>[5]</sup>, 进而影响人们的入睡时间、睡眠持续时间、睡眠深度等。在本文中, 笔者主要分析了影响睡眠质量的相关气候因素(温度、湿度、气压、氧含量、光照)并详述其作用机制, 旨在为建立健康的睡眠环境、防治睡眠障碍提供理论依据。

## 1 温度对睡眠质量的影响

## 1.1 体温节律

睡眠过程与体温节律密切相关<sup>[6]</sup>, 人体温度在

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清醒活动时上升,在睡眠时下降,并且随着睡眠程度的加深,体温下降幅度也相应增大。人体温度主要分为皮肤温度和核心温度两部分,皮肤温度容易受外界温度的影响,而核心温度则相对稳定,以确保身体各器官维持其生理功能。

皮肤温度受环境温度的影响较大,环境温度主要通过改变皮肤温度来调节大脑区域内与睡眠调控紧密相关的热敏神经元的放电活动<sup>[7]</sup>。Egan等<sup>[8]</sup>的动物实验研究发现,皮肤温度可决定下丘脑的视前区神经元的放电活动,而参与调节睡眠和温度的神经元位于视前区。视前区中 $\gamma$ -氨基丁酸能神经元或丙氨酸能神经元的激活有助于促进睡眠<sup>[9]</sup>,且这些神经元的细胞活性随温度的升高而增强。另有研究指出,皮肤温度对睡眠的影响还可能与下丘脑后外侧区的黑色素浓缩激素神经元对快速眼动(rapid eye movement, REM)睡眠的促进密切相关<sup>[10]</sup>,REM睡眠亦被称为快波睡眠或积极睡眠,其对记忆力的存储和日间精力的恢复至关重要。Komagata等<sup>[11]</sup>的研究发现,在热中性范围内,个体的REM睡眠持续时间与环境温度呈正比,其时长甚至可增至原来的两倍。此外,相关研究还发现,较高的环境温度会增加呼吸暂停低通气指数(apnea-hypopnea index, AHI),降低最低血氧饱和度,进而加剧阻塞性睡眠呼吸暂停(obstructive sleep apnea, OSA)的严重程度<sup>[12-13]</sup>。

核心温度主要受下丘脑体温调节中枢的调控,其调定点一般在37℃左右,生理波动幅度不超过1℃,且受环境温度变化的影响较小。核心温度是机体热产生和热损失之间相互调节的结果,当热损失大于热产生时,核心温度下降,反之,核心温度升高,例如在清醒且处于运动状态的白天。研究表明,核心温度升高时会促进清醒,而核心温度的下降则有利于睡眠的诱导<sup>[6]</sup>。Kimura等<sup>[14]</sup>针对昼夜节律睡眠-觉醒障碍学龄儿童核心体温变化的研究显示,随着夜间核心温度的下降,昼夜节律睡眠-觉醒障碍患者的症状得到明显改善。

## 1.2 神经递质和基因表达

5-羟色胺和去甲肾上腺素是调控睡眠觉醒周期的关键神经递质。研究表明,二者在睡眠调节中呈现相反的作用,当去甲肾上腺素含量增加时,5-羟色胺的释放量相对减少,这种变化会扰乱正常睡眠节律;反之,则有助于维持正常的睡眠节律<sup>[15]</sup>。此外,有学者发现Cartpt、Trh、Rrxg和B9d1基因表达在睡眠调控中起着重要作用,其中Cartpt、Trh

和Rrxg基因表达具有改善睡眠质量、降低觉醒程度的功能,而B9d1基因表达的作用相反。在寒冷的环境中,血清中的5-羟色胺含量会减少,去甲肾上腺素释放量增加,Cartpt、Trh、Rrxg基因表达因受到抑制而下调,B9d1基因表达上调,这一系列变化导致睡眠质量下降,觉醒程度增加<sup>[16]</sup>;相反,在适宜的环境条件下,随着上述基因表达的正常化以及神经递质含量的平衡,睡眠质量会得到改善,觉醒程度也会相应降低。

综上所述,温度主要通过影响体温节律、OSA的严重程度、神经递质的释放以及调控基因表达等多个方面对睡眠质量产生相对积极或消极的作用。但是,现有研究在深入调查探讨剧烈温度变化或极端温度对睡眠质量的影响方面仍存在不足。鉴于温度对睡眠的调节作用,未来有必要系统地研究相关机制及具体作用。在临床上,可通过构建适宜的环境温度,达到改善患者睡眠质量或治疗睡眠相关疾病的目的。

## 2 湿度对睡眠质量的影响

适宜的环境湿度有助于延长睡眠总时间,提高睡眠质量<sup>[17]</sup>,Cao等<sup>[18]</sup>通过正交实验发现,在温度为20℃、环境湿度为55%的条件下,能够更有效地在主客观上提高睡眠质量。过高或过低的环境湿度则可能引发失眠等一系列睡眠问题,当室内环境湿度过高时,会导致夜间觉醒次数增加以及觉醒时振作度降低<sup>[19]</sup>。

睡眠分为非快速眼动(non-rapid eye movement, NREM)睡眠和REM睡眠,NREM睡眠根据睡眠深度的不同,细分为N1(入睡期)、N2(浅睡期)和N3(深睡期),其中N1和N2属于浅NREM睡眠,N3属于深NREM睡眠,也称为慢波睡眠。N3和REM睡眠对消除疲劳和恢复精力有重要作用,对评价睡眠质量有着重要影响。环境湿度对睡眠参数的影响研究显示,环境湿度的增加与N1、N3、REM睡眠、总睡眠时间以及REM和NREM睡眠中的动脉血氧饱和度<95%呈负相关,但与N2和觉醒指数的增加呈正相关<sup>[20]</sup>。

多数研究认为,环境湿度对睡眠的影响通常是和温度相伴而行的,轻微的肢体皮肤温度波动可以作为睡眠结构调节中心的独立输入因素。在相对高温环境下,环境湿度主要通过阻碍由蒸发机制引起的热量损失,即蒸发热损失,改变环境和

皮肤间水分平衡,使外周身体部位温度变化率发生变化,影响传热系数,从而影响睡眠质量<sup>[21-22]</sup>。针对环境特性对老年人睡眠质量影响的研究显示,在室内环境温度适宜且稳定的情况下,环境湿度和睡眠质量呈负相关,环境湿度越低,入睡时间越短,睡眠满意度越高<sup>[23]</sup>。然而,当体温恒定时,环境湿度的变化对睡眠没有明显影响<sup>[24]</sup>。此外,有研究表明湿热可能会干扰基底前脑腺苷的积累,腺苷系统对人类的睡眠和清醒状态发挥着重要影响,腺苷作为一种内源性睡眠调节物质,会激发促进睡眠的腹外侧视前核神经元发挥作用,从而抑制大脑区域内同觉醒相关的神经元兴奋性,其积累与睡眠需求密切相关<sup>[25]</sup>。因此,可以推测环境湿度与温度相互作用,共同影响体内腺苷的累积,进而调节与睡眠相关的神经元活性,最终影响睡眠质量。

环境湿度的变化还会影响 OSA 的严重程度。研究发现,环境湿度的改变会影响空气中的水分含量,进而改变皮肤和黏膜的湿润度,导致上呼吸道黏膜张力变化,从而影响 OSA 的严重程度<sup>[26]</sup>。AHI 同环境湿度呈正比,环境湿度的日差每增加 1%,OSA 患者的 AHI 增加 0.02~0.03 次/小时,相反,环境湿度的日差每减少 1%,OSA 患者的 AHI 减少 0.03~0.04 次/小时,由此可见微小的环境湿度波动也足以对 OSA 患者产生影响<sup>[27]</sup>。

综上所述,环境湿度可通过影响睡眠结构、传热系数、腺苷的积累以及 OSA 的严重程度来影响睡眠质量。然而,目前临床上多数研究集中于湿热对睡眠的影响,单独探究环境湿度因素对睡眠影响的研究有限,影响机制尚不完全明确。因此,未来的临床研究不仅要重视环境湿度和温度的协同作用,还要关注环境湿度对睡眠的独立影响,并进一步加强对相关机制的研究,以期为进一步改善睡眠质量提供更有力的科学依据。

### 3 气压和氧含量对睡眠质量的影响

在自然环境中,气压与氧含量呈正比,当气压下降时,氧分压也随之降低,这意味着在单位体积的空气中,氧分子数也在逐步减少。气压和氧含量的变化往往与人们的身体健康和睡眠质量息息相关。例如,气压的波动会使空气中的氧含量发生改变,从而导致人体血氧饱和度的改变,使其出现醉氧或缺氧等一系列症状,还会导致睡

眠质量的下降。有研究显示,当汉族健康人群进入高原后,低压低氧的高原环境易使血氧饱和度下降,引发急性高原反应,造成不同程度的睡眠障碍<sup>[28]</sup>。此外,气压和氧含量的变化会影响睡眠结构及其持续性,主要表现为睡眠总时间、慢波睡眠和 REM 时间的减少,以及觉醒次数和觉醒时间的增加<sup>[29]</sup>。特别是对高龄人群,在高原低气压缺氧环境中,其 N3 占比、睡眠总时间和睡眠效率更低,N1 占比更高<sup>[30]</sup>。早在 2001 年,Barash 等<sup>[31]</sup>通过随机交叉双盲研究发现,在高原低气压缺氧环境中,增加空气中的氧含量会使人们的慢波睡眠、睡眠总时间和有效睡眠指数增加,从而证实了在此环境下增加空气中的氧含量、缓解缺氧可改善睡眠质量。实验研究表明,夜间血氧饱和度与海拔呈反比<sup>[32]</sup>,这进一步验证了夜间睡眠质量与空气中氧含量、气压呈正相关。此外,相关研究还显示,AHI 同环境大气压力呈反比,大气压力越低,AHI 越高,OSA 越严重,睡眠质量越差<sup>[33]</sup>。

除了从低海拔地区到高海拔地区会引起睡眠障碍外,长期高原地区生活的人群在回到平原地区后(从高原低气压缺氧地区到低海拔高气压富氧环境),身体的生理机能难以适应平原地区的低海拔高气压富氧环境,也会出现不同程度的睡眠障碍,这种现象称为脱适应睡眠障碍,其主要表现包括入睡困难、睡眠易惊醒和睡眠深度不足等<sup>[34]</sup>。

综上所述,环境气压和氧含量的变化主要通过影响血氧饱和度、睡眠结构、睡眠持续性和 OSA 的严重程度从而影响睡眠质量。目前关于气压和氧含量对睡眠影响的研究相对有限,其具体的影响机制尚不明确。多数研究集中在低气压缺氧角度,而从高气压富氧角度的研究相对较少。因此,未来的研究应该更加全面综合,以便更有效地协助临床睡眠障碍的诊断和治疗。

### 4 光照对睡眠质量的影响

#### 4.1 自主感光视网膜神经节细胞

光信号可以通过视锥、视杆细胞将其转换为电信号,并通过视网膜神经节细胞传递到大脑,还可以通过自主感光视网膜神经节细胞(intrinsically photosensitive retinal ganglion cells, ipRGCs)对睡眠产生影响。在大脑内,ipRGCs 呈现广泛投射模式,其不仅向中央昼夜节律起搏器

视交叉上核投射,调控褪黑素的释放,进而影响睡眠-觉醒节律的发生;还可投射至与昼夜节律调节功能相关的室旁下区和束间小叶,以及与睡眠调节功能相关的腹外侧视前区和外侧下丘脑等区域,从而成为光影响昼夜节律和睡眠的主要调节物质。ipRGCs既能接受来自视锥、视杆细胞光感受器的二次信号输入,又能直接通过自身表达的感光蛋白黑视素,直接对光产生反应<sup>[35]</sup>。研究发现,在相同光照条件下,视锥细胞缺失且ipRGCs不感光型小鼠和ipRGCs不感光型小鼠的睡眠时相无明显变化,而野生型和仅保留ipRGCs型小鼠的觉醒总量减少,其REM总量、NREM总量以及睡眠总时间均有所增加<sup>[36]</sup>。

研究表明,ipRGCs对光谱中蓝色区域的波长最为敏感,其自身表达的感光蛋白黑视素优先被蓝光激活,在工作场所中,针对蓝光对睡眠质量影响的研究显示,白天暴露在富含蓝色的白光下工作,可以改善夜间疲劳状况,促进夜间睡眠质量的提升<sup>[37]</sup>。不同光色及辐照度对鸟类睡眠-觉醒节律影响的研究也显示,不同颜色的光对黑尾蜡翅雀的睡眠有着不同程度的影响,具体而言,蓝色对其睡眠有积极作用,黄绿色、琥珀色和橙色对其睡眠则产生消极作用,其中黄绿色影响最大,青色和橙色对其睡眠影响相对较小<sup>[38]</sup>。

## 4.2 光照因素

光照因素(光照强度、光暴露量和光照时间)对睡眠质量的影响还和昼夜节律相位的漂移密切相关。夜间强光刺激会使昼夜节律相位后移加剧,进而延迟入睡时间并降低睡眠质量。这一现象与光照刺激激活视交叉上核细胞,影响褪黑素分泌相位有关,例如,早晨光刺激可使褪黑素分泌相位提前,夜晚光刺激可使褪黑素分泌相位推迟<sup>[39]</sup>。

在光照强度方面,研究显示光照强度越低,个体的睡眠质量越好,特别是对于老年人来说,光线越弱,睡眠越好<sup>[40]</sup>。从光暴露量的角度来看,夜晚的光暴露量与睡眠质量呈反比,夜晚较高的光暴露量会延迟入睡时间、减少慢波睡眠时间及增加夜间睡眠扰动等;而白天的光暴露量则与睡眠质量呈正比<sup>[41]</sup>。日光对夜间睡眠的研究显示,白天接触的光照越多,个体的压力情绪和夜晚睡眠质量都会得到相应程度的改善<sup>[42]</sup>。此外,傍晚夜光对青少年不同季节睡眠影响的研究显示,因为春季比冬季自然夜晚光线(夜间光暴露)更多,导致在春季褪黑素分泌时间和入睡时间明显延迟,并且

春季的睡眠持续时间明显短于冬季<sup>[43]</sup>。光照时间的长短同样会对睡眠产生一定程度的影响,随着光照时间的延长,入睡时间和觉醒时间缩短,夜间觉醒次数减少。在光照时间对阿尔茨海默病伴发睡眠障碍患者睡眠影响的研究中,采用10 000 lux全光谱光照射30 min(对照组)和120 min(观察组),结果显示,观察组的日间过度嗜睡症状和睡眠质量相比对照组均得到了明显改善<sup>[44]</sup>,这一结果证实了光照时间与睡眠质量呈正比关系。

综上所述,光对睡眠的影响主要通过光照强度、光暴露量、光照时间及光谱特征等因素影响昼夜节律的漂移和褪黑素的分泌。对于ipRGCs通路作用机制的研究,将是探究光照影响睡眠的重要方向。鉴于光照对睡眠质量的影响,临床治疗时可指导患者调整昼夜节律作息,确保充足的日间光照和减少夜间光照,以改善患者的睡眠质量,提升其整体生活质量。

## 5 结语与展望

温度、湿度、气压、氧含量和光照等是影响睡眠质量的重要气候因素。这提示在临床工作中,医护人员可指导患者通过合理调节室内温度、保持室内正常湿度、开窗通风、保持睡眠时室内暗环境等方法来改善睡眠质量,以此在一定程度上延缓或治疗某些疾病。

目前,关于气候对睡眠质量影响的研究存在诸多不足,例如,部分研究的样本量较小,导致研究结果有差异,难以推广至大众群体;一些研究的样本量虽然较大,但多采用主观问卷调查的方式,导致研究结果主观性太强,缺乏客观性和准确性;还有部分研究时间较短,只关注某一段时间的气候变化对睡眠质量的影响,缺乏对数据的长期追踪观察。鉴于此,未来相关研究应在总结过去研究的基础上,一方面增加样本量以提高研究结果的代表性;另一方面,对受试者进行长期观察追踪,以获取更全面的数据;同时,采用主观问卷调查和客观仪器测量相结合的方式,突破地域限制,开展跨学科合作,从而形成更具综合性的研究成果,为深入理解气候因素与睡眠质量之间的关系提供更有力的科学依据。

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## 参 考 文 献

- [1] LIM D C, NAJAFI A, AFIFI L, et al. The need to promote sleep health in public health agendas across the globe[J]. *Lancet Public Health*, 2023, 8 (10): e820-e826. DOI: 10.1016/S2468-2667 (23) 00182-2.
- [2] 袁亚运. 中国成年人睡眠状况与身心健康的交叉滞后分析[J]. *现代预防医学*, 2024, 51 (18): 3416-3421, 3456. DOI: 10.20043/j.cnki.MPM.202404038.
- YUAN Y Y. A cross-lagged analysis of sleep condition and physical & mental health among Chinese adults[J]. *Mod Prev Med*, 2024, 51 (18): 3416-3421, 3456. DOI: 10.20043/j.cnki.MPM.202404038.
- [3] 岳鸾依, 张永康. 失眠症伴抑郁、焦虑症状中西医结合论治的研究进展[J]. *新医学*, 2023, 54 (1): 26-29. DOI: 10.3969/j.issn.0253-9802.2023.01.006.
- YUE L Y, ZHANG Y K. Research progress on integrated traditional Chinese and Western medicine treatment of insomnia complicated with anxiety and depression[J]. *J New Med*, 2023, 54 (1): 26-29. DOI: 10.3969/j.issn.0253-9802.2023.01.006.
- [4] ZHENG X, ZHANG K, ZHAO Y, et al. Environmental chemicals affect circadian rhythms: an underexplored effect influencing health and fitness in animals and humans[J]. *Environ Int*, 2021, 149: 106159. DOI: 10.1016/j.envint.2020.106159.
- [5] GUBBI S, WURTH R, SHMOUNI F H, et al. Environmental endocrinology[M]. PALIOURA E, KANDARAKI E A, DIAMANTI-KANDARAKIS E. *Environmental endocrinology and endocrine disruptors: endocrine and endocrine-targeted actions and related human diseases*. Berlin: Springer, 2023.
- [6] SAKAMOTO H, YOSHIDA Y, YUDA E. Prediction of sleep indices using continuous data analysis of core body temperature variation[J]. *Int Symp Affect Sci Eng*, 2023, ISASE2023: 1-3. DOI: 10.5057/isase.2023-c000006.
- [7] VAN SOMEREN E J W. Mechanisms and functions of coupling between sleep and temperature rhythms[J]. *Prog Brain Res*, 2006, 153: 309-324. DOI: 10.1016/S0079-6123 (06) 53018-3.
- [8] EGAN G F, JOHNSON J, FARRELL M, et al. Cortical, thalamic, and hypothalamic responses to cooling and warming the skin in awake humans: a positron-emission tomography study[J]. *Proc Natl Acad Sci USA*, 2005, 102 (14): 5262-5267. DOI: 10.1073/pnas.0409753102.
- [9] FAN Y, WANG Y, GU P, et al. How temperature influences sleep[J]. *Int J Mol Sci*, 2022, 23 (20): 12191. DOI: 10.3390/ijms232012191.
- [10] KROEGER D, BANDARU S S, MADARA J C, et al. Ventrolateral periaqueductal gray mediates rapid eye movement sleep regulation by melanin-concentrating hormone neurons[J]. *Neuroscience*, 2019, 406: 314-324. DOI: 10.1016/j.neuroscience.2019.03.020.
- [11] KOMAGATA N, LATIFI B, RUSTERHOLZ T, et al. Dynamic REM sleep modulation by ambient temperature and the critical role of the melanin-concentrating hormone system[J]. *Curr Biol*, 2019, 29 (12): 1976-1987.e4. DOI: 10.1016/j.cub.2019.05.009.
- [12] LI A, ZHANG Q, YAO Y, et al. Higher ambient temperatures may worsen obstructive sleep apnea: a nationwide smartwatch-based analysis of 6.2 million person-days[J]. *Sci Bull*, 2024, 69 (13): 2114-2121. DOI: 10.1016/j.scib.2024.05.016.
- [13] STAATS R, BAILLY S, BONSIGNORE M R, et al. Impact of temperature on obstructive sleep apnoea in three different climate zones of Europe: Data from the European Sleep Apnoea Database (ESADA)[J]. *J Sleep Res*, 2021, 30 (5): e13315. DOI: 10.1111/jsr.13315.
- [14] KIMURA S, TAKAOKA Y, TOYOURA M, et al. Core body temperature changes in school-age children with circadian rhythm sleep-wake disorder[J]. *Sleep Med*, 2021, 87: 97-104. DOI: 10.1016/j.sleep.2021.08.026.
- [15] 许饶缤. 寒地城市青年人群睡眠情况调查及针刺对寒冷因素下失眠大鼠血清 5-HT、NE 水平影响[D]. 哈尔滨: 黑龙江中医药大学, 2023. DOI: 10.27127/d.cnki.ghlzu.2023.000354.
- XU R B. Investigation on sleep status of urban youth in cold region and effect of acupuncture on serum 5-HT and NE levels of insomnia rats under cold factors[D]. Harbin: Heilongjiang University of Chinese Medicine, 2023. DOI: 10.27127/d.cnki.ghlzu.2023.000354.
- [16] 王鹏博. 寒冷条件干预大鼠差异表达基因分析及针刺对寒冷条件失眠大鼠睡眠质量的影响: 基于寒地中年人群睡眠质量调查[D]. 哈尔滨: 黑龙江中医药大学, 2023. DOI: 10.27127/d.cnki.ghlzu.2023.000091.
- WANG P B. Analysis of differentially expressed genes in rats interfered with cold condition and effect of acupuncture on sleep quality of insomnia rats in cold condition: based on the survey of sleep quality of middle-aged people in cold areas[D]. Harbin: Heilongjiang University of Chinese Medicine, 2023. DOI: 10.27127/d.cnki.ghlzu.2023.000091.
- [17] ZHENG C, HUANG W Y, WONG S H. Associations of weather conditions with adolescents' daily physical activity, sedentary time, and sleep duration[J]. *Appl Physiol Nutr Metab*, 2019, 44 (12): 1339-1344. DOI: 10.1139/apnm-2019-0309.
- [18] CAO T, LIAN Z, MA S, et al. Thermal comfort and sleep quality under temperature, relative humidity and illuminance in sleep environment[J]. *J Build Eng*, 2021, 43: 102575. DOI: 10.1016/j.jobe.2021.102575.
- [19] 刘松敏, 王芳, 牛元源, 等. 夜间开窗角度对室内空气质量和睡眠质量的影响[J]. *建筑热能通风空调*, 2022, 41 (5): 28-33, 13. DOI: 10.3969/j.issn.1003-0344.2022.05.007.
- LIU S M, WANG F, NIU Y Y, et al. Influence of window angle at night on indoor air quality and sleep quality[J]. *Build Energy Environ*, 2022, 41 (5): 28-33, 13. DOI: 10.3969/j.issn.1003-0344.2022.05.007.
- [20] LIU W T, WANG Y H, CHANG L T, et al. The impacts of ambient relative humidity and temperature on supine position-related obstructive sleep apnea in adults[J]. *Environ Sci Pollut Res Int*, 2022, 29 (33): 50755-50764. DOI: 10.1007/s11356-022-18922-8.

- [21] MANZAR M D, SETHI M, HUSSAIN M E. Humidity and sleep: a review on thermal aspect[J]. *Biol Rhythm Res*, 2012, 43(4): 439-457. DOI: 10.1080/09291016.2011.597621.
- [22] LEE H Y, KIM S H. Effect of exercise and light exposure on sleep and sleep related factors in elderly women[J]. *Int J Health Sci*, 2023: 1123-1130. DOI: 10.53730/ijhs.v6ns10.13822.
- [23] 闫博. 西安市老年人睡眠环境特性及其对睡眠质量的影响[D]. 西安: 长安大学, 2022. DOI: 10.26976/d.cnki.gchau.2022.001854.
- YAN B. Characteristics of sleep environment of the elderly in Xi'an and their effects on sleep quality[D]. Xi'an: Chang'an University, 2022. DOI: 10.26976/d.cnki.gchau.2022.001854.
- [24] TELLIEZ F, BACH V, DELANAUD S, et al. Influence of incubator humidity on sleep and behaviour of neonates kept at stable body temperature[J]. *Acta Paediatr*, 2001, 90(9): 998-1003. DOI: 10.1080/080352501316978066.
- [25] CHOI I S, KIM J H, JEONG J Y, et al. Astrocyte-derived adenosine excites sleep-promoting neurons in the ventrolateral preoptic nucleus: Astrocyte-neuron interactions in the regulation of sleep[J]. *Glia*, 2022, 70(10): 1864-1885. DOI: 10.1002/glia.24225.
- [26] JOKIC R, BHAGCHANDANI L, ZINTEL T, et al. Effect of high versus low ambient humidity on the severity of obstructive sleep apnoea[J]. *Thorax*, 1999, 54(8): 711-713. DOI: 10.1136/thx.54.8.711.
- [27] BAI K J, LIU W T, LIN Y C, et al. Ambient relative humidity-dependent obstructive sleep apnea severity in cold season: a case-control study[J]. *Sci Total Environ*, 2023, 861: 160586. DOI: 10.1016/j.scitotenv.2022.160586.
- [28] 马燕, 李华, 杜红霞, 等. 短期进驻高原健康人群急性高原反应与高原环境特征、睡眠障碍的关系研究[J]. *中国国境卫生检疫杂志*, 2024, 47(6): 570-573. DOI: 10.16408/j.1004-9770.2024.06.006.
- MA Y, LI H, DU H X, et al. Relationship between high altitude environmental characteristics and acute mountain sickness and sleep disorder in healthy people entering high altitude for short time[J]. *Chin J Front Health Quarantine*, 2024, 47(6): 570-573. DOI: 10.16408/j.1004-9770.2024.06.006.
- [29] 刘晓钰, 王云英, 路志红. 不同海拔高度对人体睡眠及认知功能的影响[J]. *空军军医大学学报*, 2024, 45(12): 1464-1468. DOI: 10.13276/j.issn.2097-1656.2024.12.020.
- LIUX Y, WANG Y Y, LU Z H. Effects of different altitudes on sleep and cognitive function[J]. *J Air Force Med Univ*, 2024, 45(12): 1464-1468. DOI: 10.13276/j.issn.2097-1656.2024.12.020.
- [30] 杨凌麟, 陈宇洁, 王怡, 等. 不同海拔地区不同年龄、性别健康成人睡眠监测指标差异性及其临床意义研究[J]. *中国全科医学*, 2024, 27(24): 2961-2968. DOI: 10.12114/j.issn.1007-9572.2023.0538.
- YANG L L, CHEN Y J, WANG Y, et al. Variations and clinical significance of sleep monitoring indicators among healthy adults of different ages and genders in various altitudes[J]. *Chin Gen Pract*, 2024, 27(24): 2961-2968. DOI: 10.12114/j.issn.1007-9572.2023.0538.
- [31] BARASH I A, BEATTY C, POWELL F L, et al. Nocturnal oxygen enrichment of room air at 3800 meter altitude improves sleep architecture[J]. *High Alt Med Biol*, 2001, 2(4): 525-533. DOI: 10.1089/152702901753397090.
- [32] 庞怀霞, 郝丽娟, 凯伦, 等. 高原不同海拔地区居民日间及夜间睡眠血氧饱和度变化的研究[J]. *世界睡眠医学杂志*, 2023, 10(2): 238-240. DOI: 10.3969/j.issn.2095-7130.2023.02.005.
- PANG H X, HAO L J, KAI L, et al. Study on changes of blood oxygen saturation during daytime and night sleep in residents at different elevations of plateau[J]. *World J Sleep Med*, 2023, 10(2): 238-240. DOI: 10.3969/j.issn.2095-7130.2023.02.005.
- [33] DOHERTY M J, YOUNG C E, HALTINER A M, et al. Do weather-related ambient atmospheric-pressure changes influence sleep disordered breathing[J]. *J Clin Sleep Med*, 2010, 6(2): 152-156. DOI: 10.5664/jcsn.27764.
- [34] 张宇平, 赵坤, 安辉, 等. 高原疗养员脱适应期睡眠障碍及康复治疗研究进展[J]. *中国疗养医学*, 2024, 33(2): 43-47. DOI: 10.13517/j.cnki.ccm.2024.02.008.
- ZHANG N P, ZHAO K, AN H, et al. Research progress on sleep disorders and rehabilitation treatment during the deadaptation period of high-altitude recuperators[J]. *Chin J Conval Med*, 2024, 33(2): 43-47. DOI: 10.13517/j.cnki.ccm.2024.02.008.
- [35] LEGATES T A, FERNANDEZ D C, HATTAR S. Light as a central modulator of circadian rhythms, sleep and affect[J]. *Nat Rev Neurosci*, 2014, 15(7): 443-454. DOI: 10.1038/nrn3743.
- [36] 王媛, 吴芳, 李晓凤, 等. 光通过自主感光视网膜神经节细胞调节睡眠活动[J]. *安徽医科大学学报*, 2016, 51(4): 463-467. DOI: 10.19405/j.cnki.issn1000-1492.2016.04.001.
- WANG Y, WU F, LI X F, et al. Light induced sleep is mediated by intrinsically photosensitive retinal ganglion cells[J]. *Acta Univ Med Anhui*, 2016, 51(4): 463-467. DOI: 10.19405/j.cnki.issn1000-1492.2016.04.001.
- [37] VIOLA A U, JAMES L M, SCHLANGEN L J M, et al. Blue-enriched white light in the workplace improves self-reported alertness, performance and sleep quality[J]. *Scand J Work Environ Health*, 2008, 34(4): 297-306. DOI: 10.5271/sjweh.1268.
- [38] 牛丛涵. 不同光色及辐照度的人工光对黑尾蜡嘴雀和金翅雀睡眠节律的影响[D]. 天津: 天津大学, 2020. DOI: 10.27356/d.cnki.gtjdu.2020.002515.
- NIU C H. Effects of artificial light of different light colors and radiation on sleeping rhythm of eophona migratoria and carduelis sinica[D]. Tianjin: Tianjin University, 2020. DOI: 10.27356/d.cnki.gtjdu.2020.002515.
- [39] SCHLANGEN L J M, PRICE L L A. The lighting environment, its metrology, and non-visual responses[J]. *Front Neurol*, 2021, 12: 624861. DOI: 10.3389/fneur.2021.624861.
- [40] PUTRI A H, SATINO S, RIFAI A, et al. Effect light-intensity on sleep quality in elderly[J]. *JKG*, 2023: 89-97. DOI: 10.37341/jkg.v8i2.858.
- [41] HE M, RU T, LI L, et al. The optimization effects of daytime

- light exposure on sleep and its mechanisms[J]. *Adv Psychol Sci*, 2023, 31 (9): 1698. DOI: 10.3724/sp.j.1042.2023.01698.
- [42] FIGUEIRO M G, JARBOE C, SAHIN L. The sleep maths: a strong correlation between more daytime light and better nighttime sleep[J]. *Light Res Technol*, 2021, 53 (5): 423-435. DOI: 10.1177/14771535211005832.
- [43] FIGUEIRO M G, REA M S. Evening daylight may cause adolescents to sleep less in spring than in winter[J]. *Chronobiol Int*, 2010, 27 (6): 1242-1258. DOI: 10.3109/07420528.2010.487965.
- [44] 李星辰, 曹慧婷. 全光谱光照时间对 AD 伴发睡眠障碍患者睡眠质量、认知功能及日间过度嗜睡的影响[J]. *中国疗养医学*, 2021, 30 (6): 616-618. DOI: 10.13517/j.cnki.ccm.2021.06.017.
- LI X C, CAO H T. Effects of full-spectrum illumination time on sleep quality, cognitive function and excessive daytime sleepiness in patients with AD complicated with sleep disorder[J]. *Chin J Conval Med*, 2021, 30 (6): 616-618. DOI: 10.13517/j.cnki.ccm.2021.06.017.

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