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COMMENTARY

Sleep homeostasis in OSA: a complementary neurophysiological outcome measure

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Unidimensional characterization of obstructive sleep apnea (OSA) solely by the apnea–hypopnea index (AHI) overlooks important aspects of disease biology that influence patient-relevant outcomes. Contemporary work is increasingly incorporating metrics such as hypoxic [1] and ventilatory burden [2] to better capture disease heterogeneity and clinical impact. Sleep homeostasis (SH) offers a complementary physiological metric that may better capture the impact of OSA on brain function and restorative sleep.

The concept of SH derives from Borbély's two-process model in which sleep is governed by the interaction between a homeostatic process (Process S) and the circadian process (Process C) [3]. Slow-wave activity (SWA; EEG spectral power in the 0.5–4 Hz range during NREM sleep) is the physiological marker of Process S, rising with prolonged wakefulness and dissipating across the night [4]. Assessment of SH has since expanded beyond static SWA power to its overnight dynamics, including the rate of SWA decay and the change in slow-wave slope across successive NREM cycles [5].

The synaptic homeostasis hypothesis of Giulio Tononi and Chiara Cirelli extends this framework, positing that sleep downscales or renormalizes synaptic strength accumulated during wakefulness, reducing the energetic cost of synaptic maintenance, thus linking SH to synaptic plasticity, learning, memory consolidation, and restoring cerebral metabolic efficiency [6, 7]. Slow-wave sleep has also been linked to restoration of cerebral energy metabolism [6] and to glymphatic clearance of neurotoxic metabolites [8]. Impaired SH may therefore signal disrupted synaptic function and reduced restorative capacity—a rationale for evaluating the neurophysiological consequences of OSA beyond conventional sleep architecture.

In their study recently published in the Journal of Clinical Sleep Medicine, Maganti et al. leveraged Wisconsin Sleep Cohort (WSC) data to evaluate how OSA relates to SH, to examine the neurophysiological consequences of OSA [9]. Using normalized delta power—SWA—from frontal and central leads, they define three complementary measures of SH: (1) SWA decay across successive NREM clusters, (2) Slow wave slope decline from early to late NREM sleep, and (3) rebound in SWA following wake after sleep onset (WASO). Collectively, these measures reflect how the brain dissipates sleep pressure, renormalizes synaptic strength, and responds to nocturnal awakenings. Impaired homeostasis is reflected by flatter SWA decay, reduced slow wave slope decline, and absent post-WASO SWA rebound.

The study shows that SH metrics detect neurophysiological disturbances not identified by conventional sleep staging. While mean SWA did not differ between OSA severity groups, SH metrics indicated impaired sleep homeostasis, especially in participants with severe OSA. Participants with severe OSA (3% desaturation criteria) demonstrated a significantly flatter overnight SWA decay, suggesting impaired dissipation of sleep pressure. WASO failed to elicit a compensatory increase in subsequent NREM SWA in severe OSA, in contrast to no OSA and mild OSA groups. Furthermore, a physiological reduction in slow wave slope was also not observed in the severe OSA group. These observations align with the growing recognition that recurrent respiratory-related hypoxemia and sleep fragmentation disrupt restorative sleep processes in ways not captured by conventional sleep staging.

Medication use—serotonin–norepinephrine reuptake inhibitors, tricyclic antidepressants, antihypertensives, and

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sedatives—and diabetes were independently associated with impaired SH, underscoring the need to account for pharmacologic exposures and comorbidity when interpreting these metrics. Flatter SWA decay in men raises questions about sex-specific differences in sleep regulation in OSA. The association between more than 4 cups of caffeine and impaired SH is not surprising, and it is likely mediated by adenosine receptor antagonism [10].

However, the association between medication use and SH impairment must be interpreted cautiously. For instance, although benzodiazepines alter slow-wave activity [11, 12], whereas selective serotonin reuptake inhibitors have highly variable effects [13].

Ultimately, these findings reinforce that restorative sleep depends on more than just resolving respiratory events. Although continuous positive airway pressure (CPAP) effectively eliminates obstructive respiratory events, many patients continue to experience excessive daytime sleepiness or cognitive dysfunction despite optimal adherence [14, 15]. As the field moves beyond strict reliance on the AHI toward metrics that better capture disease heterogeneity—such as hypoxic [1] and ventilatory [2] burden—sleep homeostasis (SH) emerges as a promising complementary measure of brain function. Impaired dissipation of sleep pressure may represent one mechanism linking OSA-related sleep fragmentation to persistent daytime fatigue and cognitive dysfunction, providing a plausible explanation for residual symptoms despite effective CPAP therapy. In this context, it is important to note that PAP therapy often does not fully normalize sleep architecture [16]. Recognizing SH as a biomarker for physiological phenotyping aligns with a precision medicine approach, potentially explaining why patients with comparable OSA severity experience vastly different cognitive outcomes. Whether SH provides incremental prognostic value beyond stage-specific respiratory and arousal metrics (e.g., SWS-AHI or SWS arousal index) remains an important question for future studies.

Maganti et al. demonstrate that OSA alters the overnight dynamics of SWA, advancing the understanding of how sleep-disordered breathing interacts with brain physiology and positioning SH as a promising phenotyping dimension. Replication in independent and more diverse cohorts, longitudinal assessment of change with treatment, and studies linking SH to subjective, cognitive, and neurodegenerative outcomes will determine whether the measure carries incremental clinical value. If validated, SH could shift the focus of OSA assessment from counting respiratory events toward quantifying the brain's capacity to recover from them.

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Declarations

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Consent for publication Not applicable.

Competing interests Not applicable.

References

1. Azarbarzin A, Sands SA, Stone KL, Taranto-Montemurro L, Messineo L, Terrill PI, et al. The hypoxic burden of sleep apnoea predicts cardiovascular disease-related mortality: the Osteoporotic Fractures in Men Study and the Sleep Heart Health Study. Eur Heart J. 2019;40(14):1149–57. https://doi.org/10.1093/eurheartj/ehy624.
2. Parekh A, Kam K, Wickramaratne S, Tolbert TM, Varga A, Osorio R, et al. Ventilatory burden as a measure of obstructive sleep apnea severity is predictive of cardiovascular and all-cause mortality. Am J Respir Crit Care Med. 2023;208(11):1216–26. https://doi.org/10.1164/rccm.202301-0109OC.
3. Borbély AA. A two process model of sleep regulation. Hum Neurobiol. 1982;1(3):195–204.
4. Dijk DJ, Beersma DG, Daan S. EEG power density during nap sleep: reflection of an hourglass measuring the duration of prior wakefulness. J Biol Rhythms. 1987;2(3):207–19. https://doi.org/10.1177/074873048700200304.
5. Vyazovskiy VV, Cirelli C, Tononi G. Electrophysiological correlates of sleep homeostasis in freely behaving rats. Prog Brain Res. 2011;193:17–38. https://doi.org/10.1016/B978-0-444-53839-0.00002-8.
6. Tononi G, Cirelli C. Sleep and the price of plasticity: from synaptic and cellular homeostasis to memory consolidation and integration. Neuron. 2014;81(1):12–34. https://doi.org/10.1016/j.neuron.2013.12.025.
7. Tononi G, Cirelli C. Sleep function and synaptic homeostasis. Sleep Med Rev. 2006;10(1):49–62. https://doi.org/10.1016/j.smrv.2005.05.002.
8. Fultz NE, Bonmassar G, Setsompop K, Stickgold RA, Rosen BR, Polimeni JR, et al. Coupled electrophysiological, hemodynamic, and cerebrospinal fluid oscillations in human sleep. Science. 2019;366(6465):628–31. https://doi.org/10.1126/science.aax5440.
9. Maganti R, Wang J, Hetzel S. Sleep homeostasis impairment across obstructive sleep apnea severity: findings from a population-based cohort study. J Clin Sleep Med. 2026;22(1):134. https://doi.org/10.1007/s44470-026-00131-6.
10. Landolt HP, Dijk DJ, Gaus SE, Borbély AA. Caffeine reduces low-frequency delta activity in the human sleep EEG. Neuropsychopharmacology. 1995;12(3):229–38. https://doi.org/10.1016/0893-133X(94)00079-F.
11. Plante DT, Goldstein MR, Cook JD, Smith R, Riedner BA, Rumble ME, et al. Effects of oral temazepam on slow waves during non-rapid eye movement sleep in healthy young adults: a high-density EEG investigation. Int J Psychophysiol. 2016;101:25–32. https://doi.org/10.1016/j.ijpsycho.2016.01.003.
12. Zheng Y, Lv T, Wu J, Lyu Y. Trazodone changed the polysomnographic sleep architecture in insomnia disorder: a systematic review and meta-analysis. Sci Rep. 2022;12(1). https://doi.org/10.1038/s41598-022-18776-7.
13. Feige B, Voderholzer U, Riemann D, Dittmann R, Hohagen F, Berger M. Fluoxetine and sleep EEG: effects of a single dose, subchronic treatment, and discontinuation in healthy subjects. Neuropsychopharmacology. 2002;26(2):246–58. https://doi.org/10.1016/S0893-133X(01)00314-1.

14. Jennum P, Kjellberg J, Carls G, Ibsen R, Mettam S. Real-world impact of continuous positive airway pressure on sleepiness in patients with obstructive sleep apnea in a national registry. Sleep Med. 2024;118:93–100. https://doi.org/10.1016/j.sleep.2024.03.011.
15. Kushida CA, Nichols DA, Holmes TH, Quan SF, Walsh JK, Gottlieb DJ, et al. Effects of continuous positive airway pressure on neurocognitive function in obstructive sleep apnea patients: the Apnea Positive Pressure Long-term Efficacy Study (APPLES). Sleep. 2012;35(12):1593–602. https://doi.org/10.5665/sleep.2226.
16. Amicucci G, Tondo P, Mogavero MP, Vacca M, Ferri R, Ferini-Strambi L, et al. Sleep architecture impairment and cognitive performance in obstructive sleep apnea phenotypes and the effects of CPAP treatment. Sleep Med Rev. 2026;90. https://doi.org/10.1016/j.smrv.2026.102346.