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Journal homepage: <https://www.ijcap.org/>**Short Communication****Neuromodulation of sleep through electrical vestibular nerve stimulation: An update****Sai Sailesh Kumar Goothy<sup>1,\*</sup>, Rachakonda Parvathi<sup>1</sup>**<sup>1</sup>Dept. of Physiology, NRI Institute of Medical Sciences, Visakhapatnam, Andhra Pradesh, India**ARTICLE INFO***Article history:*

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**ABSTRACT**

Sleep is the state of unconsciousness where some of the bodily activities are increased and some are decreased. Adequate sleep is essential for homeostasis. Lack of adequate sleep is one of the major public health issues and needs major attention. Prolonged insomnia leads to excessive anxiety and suicidal ideation. The existing pharmacological therapies are effective and associated with side effects. Hence, there is a need for alternative therapy with minimum or no side effects. The vestibular system consists of minute sensory receptors which are basically for regulating posture. However, the vestibular system involves multiple functions related to homeostasis from the level of reflexes to the level of cognition. That is the reason why the vestibular system is called the sixth sense. There are multiple methods to stimulate the vestibular system. Linear stimulation by swinging on a swing, caloric stimulation, vestibular exercises, and electrical vestibular nerve stimulation. Whatever the method adopted, the important thing is the amount of stimulation applied. It should be an optimal stimulus to get beneficial effects from vestibular stimulation. Electrical vestibular nerve stimulation is a safe and non-invasive mode of stimulating the vestibular nerve. Animal studies demonstrated that rhythmical linear acceleration in mice promotes sleep. Here we review the mechanisms behind the sleep-promoting actions of vestibular stimulation. Understanding the mechanisms helps to plan the management of sleep disorders effectively.

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For reprints contact: [reprint@ipinnovative.com](mailto:reprint@ipinnovative.com)**1. Introduction**

Sleep is the state of unconsciousness where some of the bodily activities are increased and some are decreased. Adequate sleep is essential for homeostasis. Lack of adequate sleep is one of the major public health issues and needs major attention. Prolonged insomnia leads to excessive anxiety and suicidal ideation. This aspect is more important, especially in the age group of young adults. The sleep duration of young adults was drastically decreased. There are many reasons for this decline in sleep duration. The existing pharmacological therapies are effective and associated with side effects. Hence,

there is a need for alternative therapy with minimum or no side effects. The vestibular system consists of minute sensory receptors which are basically for regulating posture. However, the vestibular system involves multiple functions related to homeostasis from the level of reflexes to the level of cognition. That is the reason why the vestibular system is called the sixth sense. There are multiple methods to stimulate the vestibular system. Linear stimulation by swinging on a swing, caloric stimulation, vestibular exercises, and electrical vestibular nerve stimulation. Whatever the method adopted, the important thing is the amount of stimulation applied. It should be an optimal stimulus to get beneficial effects from vestibular stimulation. Electrical vestibular nerve stimulation is a safe and non-invasive mode of stimulating

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the vestibular nerve. Animal studies demonstrated that rhythmical linear acceleration in mice promotes sleep.<sup>1</sup> Gentle rocking movements through a moving bed promote nap sleep in young adults.<sup>2</sup> Gentle rocking movements were also reported to promote sleep in the elderly population.<sup>3</sup> Further, it was reported that continuous rocking promotes deep sleep.<sup>4</sup> The exact mechanism by which vestibular stimulation induce sleep is yet to be cleared. Here we review the mechanisms behind the sleep-promoting actions of vestibular stimulation. Understanding the mechanisms helps to plan the management of sleep disorders effectively.

## 2. Materials and Methods

A detailed review of published literature from <http://www.google.com>, <http://www.pubmed.com>, Medline, and other online journals was performed and analyzed using the terms vestibular stimulation, sleep, and neuromodulation.

### 2.1. Electrical vestibular stimulation (VeNS)

VeNS will be administered for 6 weeks. Each daily session will be for 1 h, with five sessions being carried out each week. Bilateral application of electrical VeNS using a battery-powered vestibular nerve stimulator (ML 1000, Neurovalence, UK) will be practiced. It consists of a headset, electrode pads, and skin swabs. The power button helps to turn on the device. The intensity of the stimulation can be controlled manually by the subject using either the buttons on the device or through the Bluetooth mobile app. After cleaning the area with swab, the electrodes are placed over each mastoid process, and then the vestibular nerves get stimulated through a gentle electrical pulse.

### 2.2. Neuromodulation of sleep through electrical vestibular nerve stimulation through the hypothalamus

Damage of the vestibular system was reported to affect the sleep-wake cycle.<sup>5</sup> The hypothalamus plays an important role in the sleep-wake cycle. In particular, the anterior hypothalamus promotes sleep and the posterior hypothalamus promotes wakefulness.<sup>6</sup> It was reported that a pathway called vestibulo-paraventricular polysynaptic pathway can modulate the stress axis's activity.<sup>7</sup> The paraventricular hypothalamic nucleus plays a key role in the arousal mechanism and damage to this nucleus leads to hypersomnia.<sup>8</sup> The vestibular system is connected with the intra-geniculate leaflet (IGL) which has widespread projections to the suprachiasmatic nucleus.<sup>9,10</sup> Vestibular stimulation causes the release of serotonin in the suprachiasmatic nucleus which is further processed into melatonin in the pineal gland. Melatonin is a key sleep inducer.<sup>11</sup>

### 2.3. Neuromodulation of sleep through electrical vestibular nerve stimulation through the dorsal raphe nucleus

The dorsal raphe nucleus consists of serotonergic and non-serotonergic neurons and plays a role in the regulation of sleep and wakefulness.<sup>12</sup> The role of serotonin in promoting sleep is well known.<sup>13</sup> Vestibular stimulation activates the midbrain<sup>14</sup> and causes the release of serotonin. This serotonin is processed in the pineal gland to convert to melatonin which induces sleep. Serotonin plays a role in sleep triggering, preparation, and maintenance.<sup>15,16</sup>

### 2.4. Neuromodulation of sleep through electrical vestibular nerve stimulation through the nucleus of tracts solitarius (NTS)

It was reported that endogenous opiates present in the nucleus of tractus solitarius are responsible for the neuromodulation of sleep.<sup>17</sup> Studies have demonstrated that there are connections between the vestibular nuclei and NTS and the neurons of NTS got activated followed by vestibular stimulation.<sup>18,19</sup>

### 2.5. Neuromodulation of sleep through electrical vestibular nerve stimulation through the Locus coeruleus (LC)

It is well-known that vestibular system stimulation inhibits the sympathetic nucleus locus coeruleus.<sup>20</sup> This inhibition is mediated through GABA.<sup>20</sup> It was reported that inhibition of the locus coeruleus promotes sleep and decreases wakefulness.<sup>21</sup> Locus coeruleus is mainly related to the sleep-wake cycle's NREM sleep.<sup>22</sup>

## 3. Conclusion

Electrical vestibular stimulation is a simple, non-invasive, and effective adjunctive therapy in the management of sleep. Hence, it is the need of time to start research studies to support the adoption of electrical vestibular nerve stimulation in the management of sleep disorders.

## 4. Source of Funding

None.

## 5. Conflict of Interest

None.

## References

1. Kompotis K, Hubbard J, Emmenegger Y, Perrault A, Mühlethaler M, Schwartz S, et al. Rocking Promotes Sleep in Mice through Rhythmic Stimulation of the Vestibular System. *Curr Biol*. 2019;29(3):392–401.
2. Sluijs RMV, Rondei QJ, Schluep D, Jäger L, Riener R, Achermann P, et al. Effect of Rocking Movements on Afternoon Sleep. *Front Neurosci*. 2020;13:1446.

3. Van Sluijs R, Rondei WE, Omlin Q, Crivelli X, Straumann F, Jäger D, et al. Gentle rocking movements during sleep in the elderly. *J Sleep Res.* 2020;29(6):e12989.
4. Perrault AA, Khani A, Quairiaux C, Kompotis K, Franken P, Muhlethaler M, et al. Whole-Night Continuous Rocking Entrain Spontaneous Neural Oscillations with Benefits for Sleep and Memory. *Curr Biol.* 2019;29(3):402–11.
5. Yan G, Li F, Tao Z, Xing X, Zhou Z, Wang X, et al. Effects of Vestibular Damage on the Sleep and Expression Level of Orexin in the Hypothalamus of Rats and Its Correlation with Autophagy and Akt Tumor Signal Pathway. *J Oncol.* 2022;2022:2514555.
6. Boes AD, Fischer D, Geerling JC, Bruss J, Saper CB, Fox MD. Connectivity of sleep- and wake-promoting regions of the human hypothalamus observed during resting wakefulness. *Sleep.* 2018;41(9):zsy108.
7. Markia B, Kovács ZI, Palkovits M. Projections from the vestibular nuclei to the hypothalamic paraventricular nucleus: morphological evidence for the existence of a vestibular stress pathway in the rat brain. *Brain Struct Funct.* 2008;213(1-2):239–45.
8. Chen CR, Zhong YH, Jiang S, Xu W, Xiao L, Wang Z, et al. Dysfunctions of the paraventricular hypothalamic nucleus induce hypersomnia in mice. *Elife.* 2021;10:e69909.
9. Horowitz SS, Blanchard JH, Morin LP. Intergeniculate leaflet and ventral lateral geniculate nucleus afferent connections: An anatomical substrate for functional input from the vestibulo-visuomotor system. *J Comp Neurol.* 2004;474(2):227–45.
10. Jacob N, Vuillez P, Lakdhar-Ghazal N, Vuillez P, Pévet P. Does the intergeniculate leaflet play a role in the integration of the photoperiod by the suprachiasmatic nucleus? *Brain Res.* 1999;828(1-2):83–90.
11. Glass JD, DiNardo LA, Ehlen JC. Dorsal raphe nuclear stimulation of SCN serotonin release and circadian phase-resetting. *Brain Res.* 2000;859(2):224–32.
12. Monti JM. The role of dorsal raphe nucleus serotonergic and non-serotonergic neurons, and of their receptors, in regulating waking and rapid eye movement (REM) sleep. *Sleep Med Rev.* 2010;14(5):319–27.
13. Monti JM. Serotonin control of sleep-wake behavior. *Sleep Med Rev.* 2011;15(4):269–81.
14. Sailesh KS, Archana R, Mukkadan JK. Vestibular stimulation: A simple but effective intervention in diabetes care. *J Nat Sci Biol Med.* 2015;6(2):321–3.
15. Cespuglio R. Serotonin: its place today in sleep preparation, triggering or maintenance. *Sleep Med.* 2018;49:31–9.
16. Sakai K. Sleep-waking discharge profiles of dorsal raphe nucleus neurons in mice. *Neuroscience.* 2011;197:200–24.
17. Cheng CH, Yi PL, Lin JG, Chang FC. Endogenous opiates in the nucleus tractus solitarius mediate electroacupuncture-induced sleep activities in rats. *Evid Based Complement Alternat Med.* 2011;2011:159209. doi:10.1093/ecam/nep132.
18. Sugiyama Y, Suzuki T, Destefino VJ, Yates BJ. Integrative responses of neurons in nucleus tractus solitaries to visceral afferent stimulation and vestibular stimulation in vertical planes. *Am J Physiol Regul Integr Comp Physiol.* 2011;301(5):1380–90.
19. Yates BJ, Grélot L, Kerman IA, Balaban CD, Jakus J, Miller AD. Organisation of vestibular inputs to nucleus tractus solitaries and adjacent structures in cat brainstem. *Am J Physiol.* 1994;267(4):974–83.
20. Nishiike S, Nakamura S, Arakawa S, Takeda N, Kubo T. GABAergic inhibitory response of locus coeruleus neurons to caloric vestibular stimulation in rats. *Brain Res.* 1996;712(1):84–94.
21. Egroo MV, Koshmanova E, Vandewalle G, Jacobs HIL. Importance of the locus coeruleus-norepinephrine system in sleep-wake regulation: Implications for aging and Alzheimer's disease. *Sleep Med Rev.* 2022;62:101592. doi:10.1016/j.smrv.2022.101592.
22. Osorio-Forero A, Cardis R, Vantomme G, Guillaume-Gentil A, Katsioudi G, Devenoges C, et al. Noradrenergic circuit control of non-REM sleep substates. *Curr Biol.* 2021;31(22):5009–23.

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