Indian Journal of Clinical Anatomy and Physiology 2023;10(2):133–135

Content available at: https://www.ipinnovative.com/open-access-journals

Indian Journal of Clinical Anatomy and Physiology

Journal homepage: https://www.ijcap.org/

Short Communication

Neuromodulation of sleep through electrical vestibular nerve stimulation: An update

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ARTICLE INFO

Article history:
Received 15-06-2023
Accepted 30-06-2023
Available online 08-07-2023

Keywords:
Electrical vestibular nerve stimulation
Sleep
Homeostasis

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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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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https://doi.org/10.18231/j.ijcap.2023.029
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the vestibular nerve. Animal studies demonstrated that rhythmical linear acceleration in mice promotes sleep.[1] Gentle rocking movements through a moving bed promote nap sleep in young adults.[2] Gentle rocking movements were also reported to promote sleep in the elderly population.[3] Further, it was reported that continuous rocking promotes deep sleep.[4] 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.[5] The hypothalamus plays an important role in the sleep-wake cycle. In particular, the anterior hypothalamus promotes sleep and the posterior hypothalamus promotes wakefulness.[6] It was reported that a pathway called vestibulo-paraventricular polysynaptic pathway can modulate the stress axis's activity.[7] The paraventricular hypothalamic nucleus plays a key role in the arousal mechanism and damage to this nucleus leads to hypersomnia.[8] The vestibular system is connected with the intra-geniculate leaflet (IGL) which has widespread projections to the suprachiasmatic nucleus.[9,10] 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.[11]

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.[12] The role of serotonin in promoting sleep is well known.[13] Vestibular stimulation activates the midbrain[14] 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.[15,16]

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.[17] Studies have demonstrated that there are connections between the vestibular nuclei and NTS and the neurons of NTS got activated followed by vestibular stimulation.[18,19]

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.[20] This inhibition is mediated through GABA.[20] It was reported that inhibition of the locus coeruleus promotes sleep and decreases wakefulness.[21] Locus coeruleus is mainly related to the sleep-wake cycle's NREM sleep.[22]

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.

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Cite this article: Goothy SSK, Parvathi R. Neuromodulation of sleep through electrical vestibular nerve stimulation: An update. *Indian J Clin Anat Physiol* 2023;10(2):133-135.