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The effects of stress on auditory system: a narrative review

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Abstract

Background Stress is an integral part of human life, small amounts of which can be effective in adapting to conditions, while its continuous increase is a predisposing factor for all diseases. The aim of this article is to determine the effect of stress on auditory system. The full text of 51 articles published between 2000 and 2023 was extracted from Scopus, PubMed, and Web of Sciences websites and became the source of this research.

Results Positive and negative emotions cause the release of stress hormones that affect all human cognitive behaviors, perceptions, and peripheral senses. They can have destructive effects on the functioning of the auditory system.

Conclusion Abnormal release of stress hormones can increase susceptibility to hearing disorders. A healthy lifestyle is essential to reduce the harmful effects of stress. The most important aspects of a healthy lifestyle are regular and uninterrupted night sleep, drinking enough water, avoiding high amounts of caffeine, a Mediterranean diet, staying away from noise/light/industrial pollution and social crimes, listening to relaxing music and doing movements in harmony with their rhythm, laughing constantly, writing down negative emotions, having true love in life, deep emotional connections with kind people, and receiving positive energy from their intentions.

Keywords Stress, Auditory, Lifestyle

Background

The structure of the human brain is very personal and unique. Experiences and events can create lasting changes in people's brains. The combination of genetic and acquired factors affects brain function and anatomy. Negative experiences caused by stress can lead to functional and structural changes in the brain of affected people in the long time [1].

Stress can be physical, such as severe pain, extreme fatigue, excessive physical activity, and pollution caused by noise/chemicals/alcohol/drugs, or it may be caused by nervous tension (fear, sadness, joy, hatred, anger) [2]. Homeostatic disturbances can also be stressful, including hunger, hypertension, thirst, chronic night waking, long airplane travel [3], hormonal changes during pregnancy, menopause, and premenstrual syndrome [4].

Paying attention to stress is an evolutionary issue that is necessary to understand human mental health in the modern lifestyle, which can increase the prevalence of physical and mental diseases and can occur at any stage of life, and it may even exist from the fetal period [3]. Stress creates the potential for organisms to adapt to changing environments, and its small amounts can be useful for improving survival [5]. It can cause disturbances in the functions of cognition, behavior, and mood and affect the physiology of systems through neuroendocrine, autonomic, immune, and metabolic mediators. Stress is associated with increases in blood pressure, pulse rate, and beta-frequency brain wave activity and decreases in alpha-delta-theta frequencies [6]

There are questions as follows: what are the mechanisms of the effects of stress on auditory system? What are the effective methods to reduce the possibility of

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damage to auditory system caused by stress? Can the positive intention of people who have deep emotional relationships with each other reduce their pain stress? Therefore, this research was conducted with the aim of determining the effect of stress on auditory system.

Methods

Inclusion criteria for this study were original research articles in English that worked on the effect of stress on auditory system. Exclusion criteria consisted of articles that examined animal studies. After a detailed search based on the titles of the articles and studying their summaries, the full text of them that met the criteria for entering this research was acquired. The search sites of this study were Scopus, MEDLINE (PubMed), and Web of Science, which were published between 2000 and 2023. Therefore, 83 documents were selected based on their titles, and after studying their abstracts, the full text of 51 articles was extracted and became the source of this research.

Results

Human perceptions and higher cognitive behaviors are disturbed under the influence of nervous tension. They can disrupt the nutrition, blood supply, and transmission of neural messages in the auditory structures [7]. The excitability of the limbic system causes disturbances in the emotional processing of sounds and increases the person's sensitivity to loudness and fear of sound, which is called hyperacusis [8]. One of the most important causes of hyperacusis is the increase in the level of stress hormones in the blood, which is a neural lesion and is caused by the stimulation of type II auditory afferent nerve fibers, which cause pain. The occurrence of hyperacusis can also be caused by the hyperactivity of afferent auditory nerve fibers [4].

Recruitment is another type of abnormal sensitivity to sound intensity that can be caused by stress and is a sensory lesion that occurs due to the damage of the outer hair cells and the activation of the inner hair cells of the cochlea [9]. The degree of hearing impairment associated with recruitment can vary from a brief temporary loss to permanent complete deafness in one or both ears [7].

The human cochlea of inner ear is equipped with immune cells. Cochlear immunocytes include macrophages and resident T cells. Macrophages phagocytose damaged hair cells in the organ of Corti, thus preventing cochlear inflammation and subsequent hearing loss. Chronic and long-term stress can lead to a decrease in phagocytosis and migration and compromise the repair process of the cochlear ganglion after injury. Macrophages are also located in the stria vascularis, where they regulate the blood-fluid barrier in the cochlea. Long-term suppression of resident macrophages through stress hormones can lead to modulation of endococcal potential, which may cause hearing loss and tinnitus [10].

The primary mechanism of tinnitus can be caused by a cochlear lesion that can be caused by noise, presbycusis, or other disorders. The onset of tinnitus is associated with damage to the hearing periphery, while the maintenance of tinnitus is associated with progressive changes in the central auditory system. Cochlear structures that may be damaged include outer and inner hair cells, supporting cells, and spiral ganglion neurons. At the molecular level, damage can be caused by glutamate toxicity, increased free radicals, and all processes leading to apoptosis [11].

At the structural level, cochlear synaptopathy is likely to be the mechanism of tinnitus initiation [12]. Arterial blood pressure is also one of the causes of tinnitus, which causes damage to cochlear microcirculation, induction of hearing loss, and deafferentation of the auditory periphery. In addition, arterial blood pressure has negative effects on the endocular potential, and it has been reported that the systolic and diastolic blood pressures of tinnitus patients at night are higher than their normal counterparts [13]. Centers involved in memory processing, including the hippocampus and parahippocampus, are implicated in the initiation and persistence of tinnitus [12].

Stress can be a predisposing factor for ear disorders, for example, Ménière's disease, sudden sensory-neural hearing loss, presbycusis, noise induce hearing loss, chronic otitis media, and neurodegenerative disorders (such as Parkinson's disease). Even stress is a predisposing factor for presbycusis at young age, which can cause dementia, central auditory processing disorder, and memory impairment in affected individuals [14]. An increase in stress is associated with the exacerbation of the symptoms of Ménière's disease, and it is believed that adrenal hormones play a role in this condition. However, patients with Ménière's have higher levels of the hormone cortisol compared to healthy individuals, which may have increased stress levels as a result of the chronicity of the disease [15]. In a large number of patients with Ménière's, the first series of attacks of dizziness, tinnitus, and deafness occur after severe stress, such as the death of relatives and various life tensions. The severity of symptoms in Ménière's disease affects the quality of life more than coping or daily stress. The physical and mental health consequences of Ménière's disease are serious for sufferers, and the stress level of affected patients is significantly worse during the acute stages of the disease than on other days [3]. There is a two-way cycle of the consequences of the physical symptoms of Ménière's disease and the psychological stress caused by it. Ménière's patients, who

have mental disorders that are more vulnerable to stress, suffer from the negative impact of this two-way cycle on their quality of life more than patients with normal mental character [14].

In addition, stress can be a predisposing factor for sudden hearing loss, which creates the condition of cochlear blood circulation disorder. Any interruption of blood flow due to thrombosis or bleeding may easily cause ischemic damage to the inner ear, resulting in irreversible sensorineural hearing loss. Diabetes, hyperlipidemia, and aging are well-known factors that contribute to microvascular and blood circulation disorders and play a role in the occurrence and prognosis of sudden hearing loss [16].

Damage to striatal synapses may be the primary cause of auditory dysfunction in noise-induced hearing loss. Oxidative stress is involved in the pathophysiology of synaptic damage. The production of reactive oxygen species leads to oxidative damage in the cochlea. This mitochondrial dysfunction consequently contributes to the loss of reactive oxygen species and causes the early onset of noise-induced hearing loss [17].

Stress can cause allostatic loads in the cognitive, emotional, and limbic systems and create incompatible structural and functional changes in the amygdala, hippocampus, and cerebral cortex. These changes include the strengthening of negative emotional memory due to the excitability of the amygdala, impairment of spatial and expressive memory in parallel with dendritic hypertrophy in the amygdala, and dendritic atrophy and reduction of neurogenesis in the hippocampus [18].

Stress activates the endocrinal glands, and they secrete corticotrophin-releasing factor, which stimulates the hypothalamus–pituitary–adrenal axis, leading to the release of cortisol and adrenaline from the adrenal glands [19]. Cortisol is a steroid hormone that is received by glucocorticoid receptors. These receptors are abundant in the central nervous system and other body organs. They are found in the human inner ear at the levels of the auditory system [20]. Glucocorticoid receptors are present in the hair cells of Corti and supporting cells (sensory tissues) and in the spiral ligaments and stria vascularis (non-sensory tissues) of the cochlea. They are involved in several mechanisms that include inner ear fluid homeostasis and signal transduction [19, 20]. When the body responds to stress, the overproduction of adrenaline reduces blood flow to the ear. Hair cells in the inner ear are very vulnerable and rely on constant blood volume to receive the right amount of oxygen and other nutrients [19].

Some brainstem nuclei, such as mesencephalic raphe nuclei and locus ceruleus, which contain serotonergic and noradrenergic neurons and are involved in auditory functions are also affected by cortisol [11]. The locus coeruleus is a dense group of cells in the lateral part of the pontine tegmentum that extends from the fourth ventricle to the facial nerve. It participates in physiological responses to stress, panic attack, and regulation of autonomic and vegetative functions. It also participates in the control of cerebral cortex blood flow, systemic blood pressure, breathing patterns, urination, arousal, sleep, food-water consumption, and the secretion of anterior pituitary hormones [10]. Cells from many regions of the brain-spinal cord, medulla, mesencephalon, hypothalamus, thalamus, amygdala, and cortex move to the locus coeruleus [21]. It forms most of the noradrenergic inputs to the limbic system. The increase in its function is associated with the activation of the sympathetic system. Reducing its performance leads to reducing stressful behaviors [10]. The median raphe nucleus contains 5-hydroxytryptamine (serotonin, 5-HT) cell bodies that give rise to the majority of the ascending 5-HT projections to the forebrain limbic areas that control emotional behavior [18].

Catecholamines are hormones produced by the adrenal glands. The main types of catecholamines are dopamine, norepinephrine, and epinephrine. Catecholamines are the main transmitters of the sympathetic nervous system. Endogenous opioids which include endorphins, enkephalins, and dynorphins are also released from the pituitary gland and limbic system during stress [19].

Endorphins are neurotransmitters released in the brain by the pituitary gland and hypothalamus, although they can also come from other parts of the body. As natural hormones, they can reduce pain, improve mood, and promote a sense of well-being [10]. Also, endorphins and enkephalins are physiological regulators of the immune response and humoral mediators between the central nervous system and the immune system. They can be considered as immunomodulators and biological response modifiers. Endorphins are released when pleasurable activities such as eating and exercise are performed [21].

Normally, endogenous opioids cause neuro-inhibition, but they may also induce neuro-excitation through dynorphin-sensitive receptors in the mammalian cochlea [22]. In the auditory system, enkephalins and dynorphins act as neurotransmitters, while noradrenaline nerve fibers were branching from the cochlear sympathetic nerve control cochlear blood flow. They surround the labyrinthine artery and branches of the medulla [23].

Discussion

Sympathetic innervation is also seen in other structures of the auditory system, including cochlear nucleus and superior olivary complex and control the activity of the

higher levels of the auditory system [4]. The endocrine response to stress can be initiated by strong auditory stimuli such as loud noises. Excitation may be transmitted through the medial geniculate body interface between the auditory system and the stress response of the limbic system [24]. The activation of the sympathetic system causes vasoconstriction and reduces the blood flow of the auditory system and the cochlea of the inner ear, which will cause ischemic damage caused by exposure to loud noise [9].

Hormones involved in the stress response may affect auditory function with an excitatory effect, leading to damage through glutamate-induced neurotoxicity [8]. The difficulty in accurately determining the effect of a single hormone on the auditory system results from the complex anatomy of the auditory system and the interactions between different hormones that occur as a result of the dynamic nature of physiological processes [23].

In order to prevent and even treat stress-pains, a healthy lifestyle can have a significant effect on reducing nervous tension and the resulting complications [25], some of which include the following:

- *Regular and sufficient night sleep*: Lack of sleep is largely associated with high levels of psychological distress and auditory-vestibular disorders such as tinnitus, vertigo, and hearing loss [26]. Since women's brains work differently from men, they have the ability to do several tasks at the same time. So, their brains need more rest. Similarly, men who have to make many decisions due to their jobs need more sleep than other men [3]. Also, short or interrupted night sleep can be stressful and increase the possibility of cognitive damages [26].
- *Drink enough water and avoid consuming large amounts of caffeine*: During stress, the adrenal glands produce excess cortisol, which increases the speed of glomerular filtration and renal plasma flow; also, by acting on mineral corticoid receptors, it increases the excretion of phosphate, sodium, water, and potassium. More secretion of cortisol due to long-term stress can increase blood pressure and cause arteriosclerosis, immune system suppression, and hearing loss. Additionally, cortisol activates mineralocorticoid receptors, leading to increased sodium reabsorption, potassium secretion, and metabolic alkalosis [27]. Overproduction of cortisol can deplete the body of vitamin C, an important antioxidants [28]. This in turn can increase oxidative stress and free radical damage, which are forms of stress. Drinking enough water can help reduce the negative physiological effects of stress [25].
- *Mediterranean diet*: Proper nutrition with a Mediterranean diet that is rich in vegetables, fruits, and antioxidants, with lower amounts of saturated fats, sugars, and animal protein, can reduce susceptibility to stress-related complications. The fats in the Mediterranean diet are omega-3 fatty acids. They are unsaturated fats that help reduce blood fat or triglycerides [25, 28].
- *Avoiding all kinds of pollutants*: A healthy lifestyle involves reducing and eliminating pollutants [29], by planting more trees and taking care of nature, reducing the use of gasoline vehicles, properly disposing of waste, minimal use of polyethylene materials, maintaining health in life [25], avoiding noisy environments and very intense lights that stimulate the nervous system [30]. Also, talking and being with reliable and intimate people can increase the level of oxytocin hormone in the blood and reduce cortisol [31]. In addition, when a person touches his/er own body, the hormone oxytocin is released. This practice is very effective for relaxation in times of stress [32]. Writing positive and negative emotions can also be effective in dealing with nervous tension and improving people's mood. This method causes coherence of thoughts, lack of fear of being judged, discharge of accumulated feelings, lightness and peace. In fact, people who suppress their nervousness and emotions have a weaker immune response to stress [33]. As well, in areas where corruption and social crimes are more and moral norms are less, the life expectancy of the residents of those areas is lower than other parts. In this situation, the percentage of suffering from physical-psychological diseases and mental-personal conflicts are also higher [25].
- *Being happy and laughing continuously*: Laughing makes a person not only happy but also healthy. When a person laughs, he automatically breathes deeper, resulting in more oxygen entering the body. Blood circulation in the heart and throughout the organs becomes more intense. The secretion of stress hormones is reduced, a sense of relaxation is created, the body's immune system is strengthened, and overall physiological functions are improved [34].
- *Listening to pleasant and relaxing music*: Music therapy can also be an effective tool to reduce stress. Soft and classical music regulates the rhythm of brain waves in the beta pattern and improves the function of the auditory-vestibular systems [31, 35]. Also, performing rhythmic movements with music in national and folklore dances, military parades, sports movements, and even chest beating during morning causes synchronization in the functions of the nerv-

ous system and increases a person's resistance in critical situations [36, 37].

- *Slow breathing during stress*: The rhythm of the brain activity is related to the heart rate, and the change in the heart rate caused by stress can cause a disturbance in the brain activity and a disturbance in hearing perception and attention. In fact, the vagus nerve runs from the brainstem to the abdomen and is part of the autonomic nervous system that controls unconscious body processes such as heart rhythm, breathing, and digestion. Overactivity of the vagus nerve can lead to an abnormal decrease in heart rate. Vagus activity increases during quiet auditory stimulation and increases the expression of a protein called c-Fos in the auditory cortex, which can cause auditory processing disorders caused by the parasympathetic nervous system. Slow breathing during stress can reduce the heart rate by the parasympathetic nervous system and improve auditory perception [38].
- *Receiving positive energy from the good intentions of people who have a deep and intimate emotional relationship with each other* [39–47]: The nature of true love is dual and contradictory, regressive and progressive, constructive and destructive, connecting and separating, and directed towards the object and the self. While losing the true love of life can be morbid, gaining and expanding it can be healing. Human history and its events are a valid document for true love and the sacrifices made by its force [32, 33]. However, there are complementary therapies to reduce pain stress that are separately from drug, surgery, counseling, and psychotherapy treatments [40]. The United States National Center for Health Statistics reported in 2004 that during a national survey of 10 complementary and alternative therapies for treating illnesses, the most popular was prayer for self and prayer with true love for others [39, 41]. Prayer for oneself is accepted based on the beneficial effects of meditation, placebos, and the plausibility of psychoimmunological models of self-regulation, which is considered a coping mechanism in the face of uncertainty or extreme need [22]. Praying with true love for others has also been confirmed as a practical coping mechanism for pain stresses [39–50]. The brain regions of anterior middle cingulate, precuneus, frontal cortexes [48], and autonomic nervous system [42] are motivated during prayer with true love [50].

Conclusion

Abnormal release of stress hormones can increase susceptibility to hearing disorders. A healthy lifestyle is essential to reduce the harmful effects of stress. The most important aspects of a healthy lifestyle are regular and uninterrupted night sleep, drinking enough water, avoiding high amounts of caffeine, a Mediterranean diet, staying away from noise/light/industrial pollution, and social crimes, listening to relaxing music and doing movements in harmony with their rhythm, laughing constantly, writing down negative emotions, having true love in life, deep emotional connections with kind people, and receiving positive energy from their intentions.

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Declarations

Ethics approval and consent to participate
This is a review study, and the Research Ethics Committee of Hamadan University of Medical Sciences does not give ethics codes to review studies.

Consent for publication
Not applicable. This study was not conducted on human samples.

Competing interests
The author declares no competing interests.

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References

1. Lenroot RK, Jay N, Giedd JN (2008) The changing impact of genes and environment on brain development during childhood and adolescence: initial findings from a neuroimaging study of pediatric twins. Dev Psychopathol. 20(4):1161–1175. https://doi.org/10.1017/S0954579408000552
2. Tang D, Tran Y, Dawes P, Gopinath B (2023) A narrative review of lifestyle risk factors and the role of oxidative stress in age-related hearing loss. Antioxidants (Basel). 12(4):878. https://doi.org/10.3390/antiox12040878
3. Pérez-Valenzuela C, Terreros G, Dagnino-Subiabre A (2018) Effects of stress on the auditory system: an approach to study a common origin for mood disorders and dementia. Neurosciences. https://doi.org/10.1515/Revneuro-2018-0018
4. Emami SF, Farahani F, Mortazavi SA (2023) Studying of distortion product of otoacoustic emissions in menopausal women. Indian J Otolaryngol Head Neck Surg 75(suppl 1):88–92. https://doi.org/10.1007/s12070-022-03210-1
5. Jia X, Kohn A (2011) Gamma rhythms in the brain. PLoS Biol 9(4):e1001045. https://doi.org/10.1371/journal.pbio.1001045
6. Emami SF, Shariatpanahi E (2023) Central representation of speech-in-noise perception: a narrative review. Aud Vestib Res 32(3):166–173. https://doi.org/10.18502/avr.v32i3.12932
7. Emami SF, Shariatpanahi E, Gohari N, Mehrabifard M (2023) Aging and speech-in-noise perception. Indian J Otolaryngol Head Neck Surg 3(21). https://doi.org/10.1007/s12070-023-03689-2

8. Martin JL, Dawson SJ, Gale JE (2022) An emerging role for stress granules in neurodegenerative disease and hearing loss. Hear Res 426(2022):108634. https://doi.org/10.1016/j.heares.2022.108634
9. Chae H et al (2021) Usefulness of stress-related hormones as predictors and prognostic factors for idiopathic sudden sensorineural hearing loss. Acta Otolaryngol 41(7):695–701. https://doi.org/10.1080/00016489.2021.1936165
10. Dantzer R. Physiol Rev (2018) Neuroimmune interactions: from the brain to the immune system and vice versa. 98(1):477-504. https://doi.org/10.1152/physrev.00039.2016. PMID: 29351513
11. Baigi A, Oden A, Almlid-Larsen V, Barrenäs ML, Holgers KM (2011) Tinnitus in the general population with a focus on noise and stress: a public health study. Ear Hear 32:787–789
12. Blum K et al (2021) Endorphinergic enhancement attenuation of post-traumatic stress disorder (PTSD) *via* activation of neuro-immunological function in the face of a viral pandemic. 10(2):86–97. https://doi.org/10.2174/2211556009999210104221215. PMID: 34466374
13. Baigi A, Oden A, Almlid-Larsen V, Barrenäs ML, Holgers KM (2021) Tinnitus in the general population with a focus on noise and stress: a public health study. Ear Hear 32:787–789
14. Orji FT (2014) The influence of psychological factors in Meniere's disease. Ann Med Health Sci Res. 4(1):3–7. https://doi.org/10.4103/2141-9248.126601
15. Kishimoto-Urata M, Urata S, Fujimoto C, Yamasoba T (2022) Role of oxidative stress and antioxidants in acquired inner ear disorders. Antioxidants (Basel). 11(8):1469. https://doi.org/10.3390/antiox11081469
16. Nitta Y et al (2023) Effect of statins on hearing outcome in patients with idiopathic sudden sensorineural hearing loss. Laryngoscope Investig Otolaryngol 8(6):1631–1636
17. Yang ZJ et al (2024) ROS-induced oxidative stress and mitochondrial dysfunction: a possible mechanism responsible for noise-induced ribbon synaptic damage. Am J Transl Res. 16(1):272–284
18. Ruan J. et al (2022) Vulnerability to chronic stress and the phenotypic heterogeneity of presbycusis with subjective tinnitus. Front Neurosci.16. https://doi.org/10.3389/fnins.2022.1046095
19. Lee SH et al (2019) Cochlear glucocorticoid receptor and serum corticosterone expression in a rodent model of noise-induced hearing loss: comparison of timing of dexamethasone administration. Sci Rep 9:12646. https://doi.org/10.1038/s41598-019-49133-w
20. Brandt T, Dieterich M (2020) Excess anxiety and less anxiety: both depend on vestibular function. Curr Opin Neurol 33(1):136–141. https://doi.org/10.1097/WCO.0000000000000771
21. Heim C, Nemeroff CB (2009) Neurobiology of posttraumatic stress disorder. CNS Spectr 14:13–24 (PMID: 19169190)
22. Hournung GP (2003) The human raphe nuclei and the serotonergic system. J Chem Neuroanat 26(4):331–343. https://doi.org/10.1016/j.jchemneu.2003.10.002
23. Qian SX et al (2019) Serum oxidative stress, inflammatory response and platelet activation in patients with vascular vertigo. J Biol Regul Homeost Agents 33(2):499–504 (PMID:30945512)
24. R Johnson JCS et al (2021) (2021) Hearing and dementia: from ears to brain. Brain. 144(2):391–401. https://doi.org/10.1093/brain/awaa429
25. Emami SF (2023) Hearing and diet. Indian J Otolaryngol Head Neck Surg. https://doi.org/10.1007/s12070-023-04238-7
26. Han KS, Kim L, Shim I (2012) Stress and sleep disorder. Exp Neurobiol 21(4):141–150. https://doi.org/10.5607/en.2012.21.4.141
27. Wassel E et al (2021) Elevated adrenocorticotropic hormone, hypercortisolism, and marked hypernatremia. Cureus 13(11):e19714. https://doi.org/10.7759/cureus.19714
28. Fan L, Zhuang Y, Wang Y et al (2020) Association of hypokalemia with cortisol and ACTH levels in Cushing's disease. Ann N Y Acad Sci 1463:60–66
29. Emami SF (2014) Acoustic sensitivity of the saccule and daf music. Iranian J Otorhinolaryngol. 75:105–10 (PMID: 24744999)
30. Boyd JE, Lanius RA, McKinnon MC (2018) Mindfulness-based treatments for posttraumatic stress disorder: a review of the treatment literature and neurobiological evidence. J Psychiatry Neurosci 43(1):7–25. https://doi.org/10.1503/jpn.170021. (Epub 2017 Oct 2)
31. Emami SF (2023) Central representation of cervical vestibular evoked myogenic potentials. Indian J Otolaryngol Head Neck Surg. https://doi.org/10.1007/s12070-023-03829-8
32. Carter CS (2022) Oxytocin and love: myths, metaphors and mysteries. Compr Psychoneuroendocrinol 9:100107. https://doi.org/10.1016/j.cpnec.2021.100107
33. Bilić VB, Eterović M, Marčinko D (2022) Psychodynamic aspects of love: a narrative review. Psychiatr Danub 34(1):3–10. https://doi.org/10.24869/psyd.2022.3
34. Akimbekov NS, Razzaque MS (2021) Laughter therapy: a humor-induced hormonal intervention to reduce stress and anxiety. Curr Res Physiol 2021(4):135–138. https://doi.org/10.1016/j.crphys.04.002. (Epub 2021 Apr 30)
35. Gohari N, Emami SF, Khavarghazalani B (2023) Comparison of the general health of parents of hearing-impaired children with early and late intervention. JRSR 10:157–161. https://doi.org/10.30476/jrsr.2022.96705.1324
36. Emami SF, Daneshi A (2012) Vestibular hearing and neural synchronization. ISRN Otolaryngology. https://doi.org/10.5402/2012/246065
37. Emami SF (2023) Sensitivity of vestibular system to sounds. Indian J Otology 29(3):141–145. https://doi.org/10.4103/indianjotol.indianjotol_19_23
38. Valenti VE et al (2019) Interaction between cortical auditory processing and vagal regulation of heart rate in language tasks: a randomized, prospective, observational, analytical and cross-sectional study. Sci Rep. https://doi.org/10.1038/s41598-019-41014-6
39. Marinelli JM, Geisler CC, Hale BA, Munson EJ (2023) Client experiences of virtual energy healing. Explore
40. Schlitz M, Radin DI, Malle BF et al (2003) Distant healing intention: definitions and evolving guidelines for laboratory studies. Alt Ther Health Med 9:A31–A43
41. Walach H (2005) Generalized entanglement: a new theoretical model for understanding the effects of complementary and alternative medicine. J Alt Comp Med 11:549–559. https://doi.org/10.1089/acm.2005.11.549
42. Radin D (2008) Testing nonlocal observation as a source of intuitive knowledge. Explore (NY). 4(1):25–35. https://doi.org/10.1016/j.explore.2007.11.001
43. Kruijthoff DJ et al (2022) Three cases of hearing impairment with surprising subjective improvements after prayer. What can we say when analyzing them? Explore. 18(4):475–482. https://doi.org/10.1016/j.explore.2021.05.00
44. Jain S, Hammerschlag R, Mills P et al (2015) Clinical studies of biofield therapies: summary, methodological challenges, and recommendations. Glob Adv Health Med 4(Suppl):58–66. https://doi.org/10.7453/gahmj.2015.034.suppl
45. Demir DM (2018) The effect of Reiki on pain: a meta-analysis. Complement Ther Clin Pract 31:384–387. https://doi.org/10.1016/j.ctcp.2018.02.020
46. Fazzino DL, Griffin MT, McNulty RS, Fitzpatrick JJ (2010) Energy healing and pain: a review of the literature. Holist Nurs Pract 24(2):79–88. https://doi.org/10.1097/HNP.0b013e3181d39718
47. Richeson NE, Spross JA, Lutz K, Peng C (2010) Effects of Reiki on anxiety, depression, pain, and physiological factors in community-dwelling older adults: physiological factors in community-dwelling older adults. Res Gerontol Nurs 3(3):187–199. https://doi.org/10.3928/19404921-20100601-01
48. Achterberg J et al (2006) Evidence for correlations between distant intentionality and brain function in recipients: a functional magnetic resonance imaging analysis. The Journal of Alternative and Complementary Medicine 11(6):71–965. https://doi.org/10.1089/acm.2005.11.965
49. Kiecolt-Glaser JK, McGuire L, Robles TF, Glaser R (2002) Psychoneuroimmunology and psychosomatic medicine: back to the future. Psychosom Med 64:15–28. https://doi.org/10.1097/00006842-200201000-00004
50. Radin D et al (2008) Compassionate intention as a therapeutic intervention by partners of cancer patients: effects of distant intention on the patients' autonomic nervous system. Explore (NY). 4(4):235–43. https://doi.org/10.1016/j.explore.2008.04. (Get rights and content)

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