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The Role of Controlled Breathing in Pain Management

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ABSTRACT
Breathing is a fundamental physiological process essential for cellular respiration and energy production. Beyond its physiological necessity, controlled breathing techniques such as yogic breathing etc. pranayama, have been practiced for centuries due to their perceived spiritual and health benefits, including stress reduction and pain management.

Recent studies have explored the physiological effects of deep slow breathing (DSB), particularly its impact on the autonomic nervous system (ANS) and pain perception. Evidence suggests that breathing at a low frequency, such as 6 h per minute (bpm), enhances heart rate variability (HRV), promotes parasympathetic activity, and reduces stress and pain levels.
This review examines the mechanisms underlying these effects, highlighting the role of the vagus nerve in regulating relaxation and reducing inflammation. Empirical studies demonstrate that DSB positively influences chronic pain conditions, including menstrual pain and visceral pain, by modulating pain perception and emotional regulation. Additionally, the combination of DSB and vagus nerve stimulation (VNS) has shown promise in managing chronic pain and improving musculoskeletal pain thresholds. Despite promising findings in menstrual pain, visceral pain, and chronic conditions, further research is needed to elucidate the mechanisms and optimize breathing techniques for pain relief. However, while DSB and VNS have demonstrated potential in reducing pain and anxiety, current research is limited in scope and methodology. Further investigations are needed to establish their long-term benefits and optimize their use in pain management strategies. This review underscores the need for a deeper understanding of the connection between controlled breathing, vagal tone, and pain relief to support their clinical application.

INTRODUCTION

Breathing is one of the most essential processes that occurs in organisms. It involves gas exchanges known in physiology as respiration - which is defined as the production of energy, typically with the intake of oxygen and the release of carbon dioxide [1]. Nowadays, its value is being more and more appreciated, as it was ages ago. Yogic breathing (pranayama) is a well-known ancient practice of controlled breathing, often performed in conjunction with meditation or yoga, for its spiritual and perceived health-enhancing effects [2]. Different breathing methods are used during psychotherapy or in hypnosis. Controlled breathing is essential in free diving, this sport discipline could not even exist without special breathing training, or by winter swimming promoters who use it as a tool to withstand low temperature. One of the most famous people who invented their own breathing method is Wim Hof, who is known for his abnormal ability to endure extremely low temperatures. Moreover, breathing is not important only for sportsmen to embrace their trainings and to achieve better results but can be introduced by every person to improve life quality. Gaining on popularity through centuries, various methods of breathing, including pranayama or mindfulness practices, became known all over the world. That is why there is a need to explore the effectiveness of breathing, its variable technics and possibilities of use. It is commonly known that deep breathing is complementary treatment strategy to manage pain. Slow breathing has been suggested to reduce the perception of pain; however, the evidence supporting this claim remains under investigation. Lehrer et al. introduced slow breathing as a non-pharmacological technique in stress management programs and biofeedback training [3]. Their findings indicated that lower heart rate variability is associated with higher levels of perceived stress. Heart rate variability, a widely used index of cardiac autonomic function, is defined as the variation in the time intervals between consecutive heartbeats and serves as a key parameter in evaluating breathing training [4].

KEYWORDS: deep breathing, breathing and pain relief, chronic pain stimulation by breathing, impact of breathing on pain, breathing and nervous system, vagus nerve stimulation, role of vagus nerve, stimulation of vagus nerve by breathing, heart rate variability.

PHYSIOLOGY OF BREATHING

Breathing is the physiological process through which the body acquires oxygen (O_2) and eliminates carbon dioxide (CO_2), both of which are critical for cellular respiration and energy production. This process, also referred to as pulmonary ventilation, is facilitated by the integrated function of the respiratory system, which includes central neural control (respiratory drive), sensory input systems, respiratory muscles, and lungs [5][6][7]. Central neural control, in conjunction with sensory input systems, regulates the timing, rate of ventilation, and air volume intake, transmitting signals to the respiratory muscles and lungs to enable the mechanical exchange of respiratory gases [8].

FREQUENCY OF BREATHING

The last decade has seen the emergence of literature documenting the effects and potential clinical benefits of slow breathing techniques, predominantly in disease states [2]. Slow breathing in research has been defined as a respiratory rate less than 10 breaths a minute (bpm) [2]. Breathing at low frequency have a positive effect on psychological stress as measured by self-report, it is used to cope with panic attack or anxiety [9] [10]. Many researchers indicate the value of 6 bpm as a beneficial - it reduces the chemoreflex response to hypercapnia and hypoxia, compared with spontaneous respiration or controlled respiration with 15 bpm [11].
In another study slow respiration (6 bpm) was found to be optimal for improving alveolar ventilation and reducing dead space (among groups of 3,6 and 15 bpm) in terms of increased arterial oxygen saturation and ease and sustainability in terms of respiratory effort [12]. This frequency turned out being crucial in reduce of pain. In the study performed among 48 participants occurred that paced breathing can reduce pain reports, the effect of lower rated pain was visible whenever they performed a paced breathing task, no matter the frequency [13]. However, this hypoalgesic effect was enhanced when breathing was paced at a lower frequency - precisely 6 bpm, and with a low prolonged expiration [13]. In the research provided by Lin I.M. et al. [14] results showed that 5.5 bpm with an inhalation-to-exhalation ratio of 5:5 increases greater heart rate variability. They examined forty-seven healthy college students and asked them to breathe in two patterns - 6 times and 5,5 times per minute with two different ratio I:E equal to 5:5 and 4:6. Heart rate variability (HRV), anxiety and relaxation levels were checked at the beginning of the test and for the four different breathing patterns. Greater HRV was achieved for 5,5 breaths with ratio 5:5, however each pattern of breathing had positive impact on relaxation. That is another proof, that breathing at low frequency reduces stress level.

DIFFERENT TYPES OF PAIN

Delving into different types of pain, the results are not exactly the same. One study indicate a significant reduction on menstrual pain perception among adolescents with primary

dysmenorrhea [15]. The study included 47 respondents whose menstrual pain was monitored in 30 minutes after the intervention.
The results showed the prevalence of menstrual pain in active adolescents with primary dysmenorrhea decreased from 76% to 22% of menstrual pain and there was a decrease in menstrual pain scores in 46.6% of respondents with moderate to severe criteria for pain experienced on the first day [15].
In another study researchers investigated the effect of deep slow breathing (DSB) on visceral pain perception - fifty-seven healthy volunteers performed controlled, deep breathing at a slow frequency (6 bpm), controlled breathing at a normal frequency (14 bpm; active control), and uncontrolled breathing (no-treatment control) in randomized order [16]. The results indicated that pain intensity was lower during DBS and normal controlled breathing, yet there was no difference between slow, deep breathing and normal controlled breathing [16]. What is more, the researchers concluded that the effect of breathing did not depend on alterations in heart rate variability or arousal, it was moderated by pain catastrophizing and suggested other underlying mechanisms [16]. Pain catastrophizing is nothing else than experiencing a pain in more exaggerated way that the average person does, ruminating on it more, and/or feeling more helpless about the experience [17]. There is a theory that suggest catastrophizing influences pain perception through altering attention and anticipation and heightening emotional responses to pain [18]. It is necessary to investigate whether the perception of pain depends on thinking about the pain itself, while the absence of pain depends on focusing one's thoughts on other activities, such as breathing at a frequency sufficient to fully dedicate oneself to that single activity.

AUTONOMIC NERVOUS SYSTEM

Another important aspect of breathing is its relationship with the autonomous system, which consists of sympathetic division known for "fight-or-flight" responses during stress and parasympathetic division which is „rest-and-digest" functions during relaxation. While the autonomic nervous system operates automatically (without conscious control), the parasympathetic branch specifically focuses on regulating relaxing activities in the body. The most important nerve, and also the longest one, which is a part of parasympathetic branch, is vagus nerve. It regulates multiple systems including cardiovascular, respiratory, immune, endocrine, and autonomic systems [19]. Its stimulation both manual and electrical, plays a key role in the neuroendocrine-immune axis to maintain homeostasis through its afferent and efferent pathways [20]. Since, the vagal tone is correlated with capacity to regulate stress responses and can be influenced by breathing, its increase through meditation and yoga likely contribute to resilience and the mitigation of mood and anxiety symptoms [21]. In other words, the increase in activity of vagal activity shift towards parasympathetic dominance providing relaxation and theoretically consequently pain relief through alleviating inflammation and modulating activities of neurons in the pain pathways [22]. The impact of DSB on an individual’s physiological and psychological state can be explained through polyvagal theory [23]. The polyvagal theory identifies the vagus nerve as a critical player in regulating the autonomic nervous system.

According to that theory deep slow breathing activates the vagus nerve through mechanoreceptors in the lungs and diaphragm and this enhances parasympathetic activity, increases vagal tone that is associated with improved emotional regulation, lower stress, and better physical health, reduces sympathetic overdrive by calming the sympathetic nervous system and promoting relaxation, enhances heart rate variability which is a key indicator of autonomic flexibility - higher HRV reflects better regulation of the nervous system, which DSB helps to achieve. There was conducted research [24] that provides empirical evidence to the thesis, it indicated that deep slow breathing seems to reduce anxiety level and increase vagal outflow (which are negatively correlated with each other) in both young and older adults, moreover deep slow breathing could have a greater effect on parasympathetic activity in older adults.

Additionally, numerous studies have been performed over the years to explore the impact of vagus nerve stimulation (VNS) on pain relief, including research specifically focused on chronic migraines [25], cluster headache [26] [27], diabetic peripheral neuropathic pain [28], fibromyalgia [29], irritable bowel syndrome [30] and others. The studies mentioned above primarily utilized two types of vagus nerve stimulation: transcervical vagus nerve stimulation (tcVNS) which stimulates vagus nerve fibers in the carotid sheath or the transauricular vagus nerve stimulation (taVNS) which stimulates the auricular branch of the vagus nerve. The study performed by Frøkjaer et al. found that combined taVNS and deep breathing modulated vagal tone and could reduce somatic pain sensitivity musculoskeletal pain thresholds in healthy subjects, therefore it can have similar promising effect in chronic musculoskeletal pain [31]. However, due to the small amount of research that has combined vagus nerve stimulation with slow breathing and limitations related to the methodology used in such studies, it is impossible to draw any conclusions at this very early stage of research [32].

CONCLUSIONS

The DSB holds significant promise as a complementary, non-pharmacological approach to pain management and stress reduction. Breathing at a low frequency, such as 6 bpm, has been shown to improve HRV, promote parasympathetic dominance, and reduce stress levels, thereby influencing both physiological and psychological states, which collectively contribute to improved physiological and psychological states. Research indicates that DSB can effectively reduce pain perception, including menstrual and visceral pain, by modulating the ANS and emotional responses to pain.

The vagus nerve emerges as a key mediator in the benefits of DSB. By enhancing vagal tone, DSB helps reduce inflammation, regulate stress responses, and improve emotional regulation. The combination of DSB with VNS has shown potential for managing chronic pain and improving musculoskeletal pain thresholds. These findings suggest that integrating DSB and VNS could provide a powerful tool for addressing both acute and chronic pain conditions. However, despite these encouraging results, further research is required to better understand the underlying mechanisms of DSB, refine protocols, and assess its long-term efficacy across a broader range of pain conditions. Future studies should aim to optimize interventions and explore the integration of DSB with other therapeutic modalities.

In summary, DSB offers a simple, accessible, and effective strategy for reducing pain, relieving stress, and enhancing overall well-being. With continued research, it may play a key role in holistic approaches to pain and stress management.

Author's contribution

Conceptualization: MW; methodology: MW; software: MG; check: MŁ; formal analysis: MW; investigation: MW and AS; resources: MG; data curation: MG and MŁ; writing- rough preparation: MW; writing-review and editing: AS and MŁ, visualization: MŁ; supervision: AS; project administration: MW; All authors have read and agreed with the published versions of the manuscript.

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REFERENCES

1. Hinic-Frlog, Sanja (2019). Introductory Animal Physiology. University of Toronto Mississauga: Pressbooks (CC BY 4.0). pp. 40–59.
2. Marc A. Russo, Danielle M. Santarelli et al. The physiological effects of slow breathing in the healthy human. Breathe 2017 13(4): 298-309
3. P.M. Lehrer, E. Vaschillo, B. Vaschillo, Resonant frequency biofeedback training to increase cardiac variability: rationale and manual for training. Appl. Psychophysiol. Biofeedback 25, 177 (2000)
4. LeWine, H.E. (2024) Heart rate variability: How it might indicate well-being, Harvard Health Publishing. Available at: https://www.health.harvard.edu/blog/heart-rate-variability-new-way-track-well-2017112212789 (Accessed: 10 January 2025).
5. Brinkman JE, Sharma S. Physiology, respiratory drive. Treasure Island: StatPearls; 2020
6. Cloutier M. Control of respiration. In: Respiratory physiology. 2nd ed. Amsterdam: Elsevier; 2018.

7. West JB, Luks AM. West's respiratory physiology: the essentials. 10th ed. Philadelphia: Wolters Kluwer; 2016.
8. Webster LR, Karan S. The Physiology and Maintenance of Respiration: A Narrative Review. Pain Ther. 2020 Dec;9(2):467-486. doi: 10.1007/s40122-020-00203-2. Epub 2020 Oct 6. PMID: 33021707; PMCID: PMC7648809.
9. Clark, D., Salkovskis, P., & Chalkley, A. (1985). Respiratory control as a treatment for panic attacks. Journal of Behavior Therapy and Experimental Psychiatry, 16(1), 23–30.
10. R. Jerath, M.W. Crawford, V.A. Barnes, K. Harden. Self-regulation of breathing as a primary treatment for anxiety. Appl Psychophysiol Biofeedback, 40 (2) (2015), pp. 107-115, 10.1007/s10484-015-9279-8
11. Bernardi, Lucianoa; Gabutti, Alessandraa; Porta, Cesarea; Spicuzza, Luciab. Slow breathing reduces chemoreflex response to hypoxia and hypercapnia, and increases baroreflex sensitivity. Journal of Hypertension 19(12):p 2221-2229, December 2001.
12. Bernardi, Luciano et al. Effect of breathing rate on oxygen saturation and exercise performance in chronic heart failure. The Lancet, Volume 351, Issue 9112, 1308 - 1311
13. Hassan Jafari, Ali Gholamrezaei, Mathijs Franssen, Lukas Van Oudenhove, Qasim Aziz, Omer Van den Bergh, Johan W.S. Vlaeyen, Ilse Van Diest, Can Slow Deep Breathing Reduce Pain? An Experimental Study Exploring Mechanisms, The Journal of Pain, Volume 21, Issues 9–10, 2020, Pages 1018-1030, ISSN 1526-5900.
14. I.M. Lin, L.Y. Tai, S.Y. Fan, Breathing at a rate of 5.5breaths per minute with equal inhalation-to-exhalation ratio increases heart rate variability, International Journal of Psychophysiology, Volume 91, Issue 3, 2014, Pages 206-211, ISSN 0167-8760,
15. Kurniati Devi Purnamasari*, Tita Rohita, Dini Nurbaeti Zen, Widya Maya Ningrum .The Effect of Deep Breathing Exercises on Menstrual Pain Perception in Adolescents with Primary Dysmenorrhea. Faculty of Health Sciences, Universitas Galuh, 46274, Ciamis, West Java Indonesia
16. Gholamrezaei A, Van Diest I, Aziz Q, et al. Effect of slow, deep breathing on visceral pain perception and its underlying psychophysiological mechanisms. Neurogastroenterol Motil. 2022; 34(4):e14242. (In eng). doi:10.1111/nmo.14242
17. Van Damme, S.; Crombez, G.; Bijttebier, P.; Goubert, L.; Houdenhove, B. V. (2001). "A confirmatory factor analysis of the Pain Catastrophizing Scale: invariant factor structure across clinical and non-clinical populations". International Association for the Study of Pain. 96 (3): 319–324. doi:10.1016/S0304-3959(01)00463-8. PMID 11973004. S2CID 19059827.
18. Gracely, R. H.; Geisser, M. E.; Giesecke, T.; Grant, M. A.; Petzke, F.; Williams, D. A.; Clauw, D. J. (2004). "Pain catastrophizing and neural responses to pain among persons with fibromyalgia". Brain. 127 (4): 835–843. doi:10.1093/brain/awh098. PMID 14960499.
19. Berthoud HR, Neuhuber WL. Functional and chemical anatomy of the afferent vagal system. Auton Neurosci. 2000;85(1–3):1–17. 10.1016/S1566-0702(00)00215-0.
20. Howland RH. Vagus Nerve Stimulation. Curr Behav Neurosci Rep. 2014 Jun;1(2):64-73. doi: 10.1007/s40473-014-0010-5. PMID: 24834378; PMCID: PMC4017164.

21. Breit S, Kupferberg A, Rogler G, Hasler G. Vagus Nerve as Modulator of the Brain-Gut Axis in Psychiatric and Inflammatory Disorders. Front Psychiatry. 2018 Mar 13;9:44. doi: 10.3389/fpsyt.2018.00044. PMID: 29593576; PMCID: PMC5859128.
22. Shao P, Li H, Jiang J, Guan Y, Chen X, Wang Y. Role of Vagus Nerve Stimulation in the Treatment of Chronic Pain. Neuroimmunomodulation. 2023;30(1):167-183. doi: 10.1159/000531626. Epub 2023 Jun 27. PMID: 37369181; PMCID: PMC10614462.
23. Porges, S. The polyvagal perspective. Biol. Psychol. 74, 116–143. https://doi.org/10.1016/j.biopsycho.2006.06.009 (2007).
24. Magnon, V., Dutheil, F. & Vallet, G.T. Benefits from one session of deep and slow breathing on vagal tone and anxiety in young and older adults. Sci Rep 11, 19267 (2021). https://doi.org/10.1038/s41598-021-98736-9
25. Najib U, Smith T, Hindiyeh N, Saper J, Nye B, Ashina S, et al. Non-invasive vagus nerve stimulation for prevention of migraine: the multicenter, randomized, double-blind, sham-controlled PREMIUM II trial. Cephalalgia. 2022;42(7):560–9. 10.1177/03331024211068813.
26. Silberstein SD, Mechtler LL, Kudrow DB, Calhoun AH, McClure C, Saper JR, et al. Non-invasive vagus nerve stimulation for the ACute treatment of cluster headache: findings from the randomized, double-blind, sham-controlled ACT1 study. Headache. 2016;56(8):1317–32. 10.1111/head.12896.
27. Gaul C, Diener H-C, Silver N, Magis D, Reuter U, Andersson A, et al. Non-invasive vagus nerve stimulation for PREVention and Acute treatment of chronic cluster headache (PREVA): a randomised controlled study. Cephalalgia. 2016;36(6):534–46. 10.1177/0333102415607070.
28. Wang S, Zhai X, Li S, McCabe MF, Wang X, Rong P. Transcutaneous vagus nerve stimulation induces tidal melatonin secretion and has an antidiabetic effect in Zucker fatty rats. PLoS One. 2015;10(4):e0124195. 10.1371/journal.pone.0124195.
29. Kutlu N, Özden AV, Alptekin HK, Alptekin JÖ. The impact of auricular vagus nerve stimulation on pain and life quality in patients with fibromyalgia syndrome. BioMed Res Int. 2020;2020:8656218. 10.1155/2020/8656218.
30. Shi X, Hu Y, Zhang B, Li W, Chen JD, Liu F. Ameliorating effects and mechanisms of transcutaneous auricular vagal nerve stimulation on abdominal pain and constipation. JCI Insight. 2021;6(14):e150052. 10.1172/jci.insight.150052.
31. Frøkjaer JB, Bergmann S, Brock C, Madzak A, Farmer AD, Ellrich J, et al. Modulation of vagal tone enhances gastroduodenal motility and reduces somatic pain sensitivity. Neurogastroenterol Motil. 2016;28(4):592–8. 10.1111/nmo.12760.
32. Transcutaneous Auricular Vagus Nerve Stimulation Combined With Slow Breathing: Speculations on Potential Applications and Technical Considerations
Szulczewski, Mikołaj Tytus Neuromodulation, Volume 25, Issue 3, 380 - 394