Review Article

Heart Rate Changes in Contexts of Acute and Chronic Pain

ABSTRACT

Aims: To investigate the relationship between heart rate variability (HRV) and acute and chronic pain, focusing on its potential as an objective tool for pain assessment.

Study Design: Integrative literature review.

Place and Duration of Study: The study was conducted through database searches (SCIELO, PUBMED, LILACS, BVS, and MEDLINE) between January 2023 and March 2023.

Methodology: This review used an integrative approach, analyzing studies that explored HRV in the context of acute and chronic pain. The databases searched were SCIELO, PUBMED, LILACS, BVS, and MEDLINE, and search terms included **"Heart** Rate Variability (HRV)", "Acute Pain", and "Chronic Pain". A total of 15 articles were initially identified, with 11 included in the final qualitative synthesis based on methodological robustness, including systematic reviews, meta-analyses, and randomized clinical trials.

Results: A significant reduction in HRV was observed in patients experiencing chronic pain, which indicates parasympathetic nervous system dysfunction. In acute pain scenarios, HRV typically decreases, reflecting increased sympathetic activity and reduced parasympathetic response. Differences in HRV changes were also noted based on age and gender, with young adults experiencing greater autonomic reactivity compared to older individuals, and men showing more substantial HRV reduction in response to acute pain compared to women.

Conclusion: HRV demonstrates promise as an objective indicator for assessing pain, especially in non-communicative patients, providing healthcare professionals with an additional tool to assess pain severity and the efficacy of interventions. However, more research is necessary to standardize HRV measurement techniques and to explore its clinical applications across different populations and health conditions.

Keywords: Heart Rate Variability, Acute Pain, Chronic Pain, Autonomic Nervous System, Pain Assessment, Sympathetic Activation, Parasympathetic Dysfunction.

1. INTRODUCTION

The International Association for the Study of Pain (IASP) recently revised the definition of pain, describing it as "a distressing experience associated with actual or potential tissue damage, encompassing sensory, emotional, cognitive, and social components"(1). Thus, pain is characterized as a subjective symptom that is difficult to measure, traditionally assessed through self-reporting[16].

Uncontrolled pain results in respiratory, hemodynamic, and metabolic changes, predisposing the patient to cardiovascular instability, increased energy and protein consumption, difficulty in early ambulation, and increased risk of deep vein thrombosis (DVT), especially in elderly patients undergoing extensive surgeries (2;3). Furthermore, uncontrolled pain can impair sleep, leading to greater physical wear, fatigue, and reduced motivation to cooperate with treatment[17,18].

The measurement of pain experience is a challenging task due to the complexity of the phenomenon and the lack of an ideal measurement tool that allows precise and accurate access to what the patient is feeling [23,24,25]. The American Pain Society defines pain as the fifth vital sign, which must always be assessed along with other vital signs, such as temperature, respiratory rate, heart rate, and blood pressure, at the time of patient admission (4). Pain assessment assists in diagnosing the presented problem and is crucial for continued care and treatment during consultations or hospitalization (5).

It is known that the activity of the sympathetic and parasympathetic nervous systems is altered in conditions of chronic pain, such as chronic low back pain, pain in the neck and shoulder region, fibromyalgia, complex regional pain syndrome, and phantom limb pain. In this regard, dysregulation of autonomic balance can be measured using Heart Rate Variability (HRV), a marker of vagal components of the sinoatrial node of the heart that measures changes in beat-to-beat intervals (6)[19].

Heart Rate Variability (HRV) is a vital sign that can be used to assess pain, especially in non-communicative patients. Pain causes modifications in vital signs such as blood pressure, respiratory rate, and heart rate, as well as significantly influencing body temperature (7) [20]. Thus, HRV, which reflects changes in heart rate, may be a potentially useful tool for healthcare professionals in pain assessment, as its variations indicate the body's physiological responses to pain, allowing for a more accurate analysis of pain sensitivity and its effects on vital signs (8)[21,22].

However, the quantification of pain is subjective since it relies on analog scales and depends on each individual's perception of pain. This leads to subjective and often inaccurate diagnoses. Therefore, it is essential to quantify pain correctly, in a non-subjective manner, based on physiological signs.

2. MATERIAL AND METHODS

The research was conducted using an integrative literature review approach, similar to the methodology used in the study on nutritional deficiency and ADHD. The search terms used were "Heart Rate Variability (HRV)", "Acute Pain", and "Chronic Pain", connected by the "AND" operator. The databases employed were SCIELO, PUBMED, LILACS, BVS, and MEDLINE. The initial selection identified 15 articles, of which 11 were included in the qualitative synthesis due to their methodological relevance, such as systematic reviews, meta-analyses, and randomized clinical trials.

Studies that utilized robust methodologies, such as randomized clinical trials and systematic reviews, explicitly addressing the relationship between heart rate variability and autonomic modulation in pain contexts, were included. Articles that were not freely available in full text were excluded, as well as those that did not use rigorous methodologies, such as uncontrolled observational studies, due to the high risk of bias. Additionally, studies that did not present a representative sample or had significant methodological flaws were eliminated. After the initial screening of the 15 identified articles, 14 were assessed for eligibility and 11 were included in the qualitative synthesis. Four articles were excluded due to the lack of free access and for not meeting the rigorous methodological criteria defined.

This review faced limitations regarding access to certain full articles, which were behind paywalls, potentially impacting the comprehensiveness of the results presented. Furthermore, a possible publication bias is present, as studies with negative or null results tend to be less published, limiting the representation of available evidence. These limitations influence the interpretation of the findings, as the lack of access to important articles may overestimate or underestimate the relationship between heart rate variability and the autonomic response to pain. To minimize these effects, a rigorous screening methodology was employed, though it is acknowledged that greater access to relevant articles is necessary for a balanced view of the topic.

3. RESULTS AND DISCUSSION

Heart Rate Variability (HRV) and Pain

In chronic pain, a significant reduction in heart rate variability (HRV) has been observed in patients with chronic pain, indicating dysfunction of the parasympathetic nervous system. In patients with fibromyalgia and chronic fatigue syndrome, reduced HRV was consistently observed, suggesting an abnormal sympathovagal balance (9). In acute pain situations, HRV tends to decrease, reflecting increased sympathetic activity and reduced parasympathetic activity. This suggests that HRV can be used as an index of the autonomic nervous system's (ANS) reactivity to pain (9,10).

The modulation of acute pain is often associated with an increased heart rate (HR) and a reduced HRV, reflecting an autonomic nervous system (ANS) stress response (10). Studies have shown that HRV is a reliable method for assessing autonomic modulation during acute pain, with individuals showing significant changes in HRV that indicate increased sympathetic activity and decreased parasympathetic activity (11). Changes in HRV may reflect sympathetic predominance, often observed in patients with chronic pain (12). Endogenous pain modulation is associated with resting HRV and negative affectivity, and studies suggest that higher HRV is correlated with a better ability to modulate pain, whereas reduced HRV may indicate a defective pain modulation system, particularly in chronic pain conditions such as fibromyalgia (11).

Patterns and Trends Related to Acute and Chronic Pain

Most studies show a significant reduction in heart rate variability (HRV) in patients with chronic pain. This reduction is associated with dysfunction of the parasympathetic nervous system, indicating a predominance of sympathetic activity in conditions of persistent pain (6, 13). Patients with conditions such as fibromyalgia, chronic fatigue syndrome, and chronic neck and shoulder pain consistently exhibited reduced HRV, suggesting autonomic imbalance (6, 10).

In contexts of acute pain, HRV tends to decrease, reflecting increased sympathetic activity. This is observed in experiments where pain is induced in healthy individuals, resulting in changes in HRV that indicate the reactivity of the autonomic nervous system (ANS) to the pain stimulus (6, 11). Endogenous pain modulation is correlated with resting HRV. Studies suggest that higher HRV is associated with better pain modulation ability (6).

Chronic pain may develop from initial trauma that triggers episodes of acute pain that evolve into chronic pain. Degenerative changes have also been suggested as underlying causes, although tissue damage is not required for chronic pain to develop. Psychological factors, such as emotional trauma and stress, are associated with the etiology of chronic pain. Central sensitization and reduced inhibitory mechanisms are often found in patients with chronic pain, indicating increased sympathetic activation and reduced parasympathetic activation. Spinal surgeries are frequently associated with postoperative complications, including persistent chronic pain. Approximately 10-40% of patients who undergo lumbar surgeries develop chronic pain, significantly affecting quality of life (14).

Age Effects

In neonates and infants, the autonomic response to acute pain is more pronounced. Studies indicate that HRV is a sensitive measure for assessing pain in these age groups. Premature neonates exhibit a differentiated autonomic response to pain, with lower heart rate variability compared to full-term neonates (9). HRV tends to decrease with age, regardless of the presence of pain. However, in young adults, acute pain induces a more significant reduction

in HRV compared to the elderly, suggesting greater autonomic reactivity in younger individuals (13).

Gender Effects

The autonomic modulation of pain can vary between men and women. Men tend to show a greater reduction in HRV in response to acute pain compared to women. Hormonal differences and variation in stress responses are possible factors contributing to these differences (9). Interventions such as manual therapy can have different effects between genders. For example, men may respond more quickly to spinal manipulation techniques in terms of increasing HRV, while women may show more variable responses depending on the menstrual cycle (6).

Effects by Health Condition

Individuals with chronic pain conditions, such as fibromyalgia, show a significant reduction in HRV, indicating autonomic imbalance. Interventions, such as HRV biofeedback, have shown efficacy in improving autonomic modulation and reducing pain symptoms in these patients (10, 13). In patients with traumatic brain injuries, HRV can be used to monitor pain and stress. However, the autonomic response to pain may be blunted due to damage to the central nervous system, resulting in lower HRV compared to healthy individuals (9).

Although significant changes have been observed in some physiological parameters under Hypnotic Virtual Reality (HVR), such as decreased respiratory rate and skin conductance response (SCR), no effect was detected in time-domain measures of heart rate variability. This suggests that HVR may not directly influence these cardiac parameters in contexts of acute and chronic pain during the described experiments (15).

Conflicting or Discrepant Results

Some studies indicate that interventions such as manual therapy have an immediate effect on HRV, while others found no significant changes after treatment; for example, adding four sessions of spinal manipulative therapy to a home-based stretching exercise program did not result in significant HRV changes. Conflicting results were also observed in studies investigating the impact of different spinal manipulation techniques on HRV, with some systematic reviews reporting acute autonomic responses to various spinal manipulation therapy (SMT) techniques, while others did not find robust evidence due to the low quality of the included studies (6, 11).

HRV can be influenced by various factors beyond pain, such as emotional stress, physical activity, and pre-existing medical conditions, which can lead to variations in results;

studies that do not adequately control these factors may present conflicting findings about the relationship between HRV and pain (6).

4. CONCLUSION

A literature review demonstrated that a significant decrease in HRV is associated with chronic pain (9, 13), suggesting parasympathetic nervous system dysfunction. Acute pain leads to increased sympathetic activity and decreased HRV, which results from the autonomic nervous system's stress response (11).

These findings are important for clinical practice because they suggest that HRV may be a useful and objective tool for pain assessment, especially in non-communicative patients. Using HRV as a physiological marker can help medical professionals more accurately assess pain intensity and the effectiveness of therapeutic interventions. Differences in autonomic responses to pain among different age groups and sexes were also highlighted, indicating the need for individualized approaches to pain management.

While the autonomic response to acute pain is more pronounced in neonates and infants, acute pain causes a greater reduction in HRV in young adults compared to older adults. Furthermore, compared to women, men tend to experience a greater reduction in HRV in response to acute pain, likely due to differences in hormonal and stress responses.

Factors such as age, gender, and pre-existing health conditions, like cardiac issues, can influence HRV, requiring a more contextual analysis. Therefore, future research should focus on standardizing HRV measurement methods and exploring new continuous and non-invasive monitoring techniques.

The reviewed literature, including recent studies, emphasizes the importance of non-subjective methods in pain assessment and provides valuable information for pain management in clinical practice. In summary, HRV appears promising as an objective measure for pain assessment and has the potential to significantly improve pain monitoring and treatment methods in clinical practice. Further research is needed to standardize the clinical use of HRV and examine its effectiveness across different populations and health conditions.

REFERENCES

1. Williams, A. C. de C., & Craig, K. D. (2016). Updating the definition of pain. *Pain, 157*(11), 2420-2423. https://doi.org/10.1097/j.pain.0000000000000613

2. Dos Santos Kanematsu, J., Atanazio, B., Cunha, B. F., & Caetano, L. P. (2022). Impacto da dor na qualidade de vida do paciente com dor crônica. *Revista de Medicina, 101*(3).
3. Ferrari, M. F. M., Daher, D. V., De Macedo Antunes, J., Amim, E. F., et al. (2019). A dor como quinto sinal vital, desafios para a incorporação na formação em saúde. *REME-Revista Mineira de Enfermagem, 23*(1).
4. Viveiros, W. L., Okuno, M. F. P., Campanharo, C. R. V., Lopes, M. C. B. T., et al. (2018). Pain in emergency units: correlation with risk classification categories. *Revista Latino-Americana de Enfermagem, 26*.
5. Dik, A. B., & Lohmann, P. M. (2020). A dor no contexto da urgência e emergência: uma revisão integrativa. *Research, Society and Development, 9*(4).
6. Harper, B., Price, P., & Steele, M. (2023). The efficacy of manual therapy on HRV in those with long-standing neck pain: a systematic review. *Scandinavian Journal of Pain, 23*(4), 623-637.
7. Young, J., Siffleet, J., Nikoletti, S., & Shaw, T. (2006). Use of a Behavioural Pain Scale to assess pain in ventilated, unconscious and/or sedated patients. *Intensive and Critical Care Nursing, 22*(1), 32-39.
8. Kawagoe, C. K., Matuoka, J. Y., & Salvetti, M. D. G. (2017). Pain assessment tools in critical patients with oral communication difficulties: a scope review. *Revista Dor, 18*.
9. Korving, H., et al. (2020). Physiological measures of acute and chronic pain within different subject groups: a systematic review. *Pain Research and Management, 1*, 9249465.
10. Viti, A., et al. (2023). Modulation of heart rate variability following PAP ion magnetic induction intervention in subjects with chronic musculoskeletal pain: A pilot randomized controlled study. *International Journal of Environmental Research and Public Health, 20*(5), 3934.
11. Biral, T. M., et al. (2023). Effects of remote ischemic conditioning on conditioned pain modulation and cardiac autonomic modulation in women with knee osteoarthritis: placebo-controlled randomized clinical trial protocol. *Trials, 24*(1), 502.
12. Wu, X., Yu, S., Shen, Z., Chen, Q., Liu, J., Liu, K., et al. (2022). Perioperative transcutaneous electrical acupoint stimulation (pTEAS) in pain management in major spinal surgery patients. *BMC Anesthesiology, 22*(1), 342.
13. Baroni, D. A., Oliveira, E. M., Silva Jr., E. A., Haddad, A. S., & Tardelli, M. A. (2022). Comparison between Analgesia Nociception Index (ANI) and self-

reported measures for diagnosing pain in conscious individuals: a systematic review and meta-analysis. *Scientific Reports, 12*(1), 2862.

14. Galaasen Bakken, A., Wisloff-Aase, A., Loras, H., Røe, C., Schistad, E. I., Glette, M., et al. (2021). The effect of spinal manipulative therapy and home stretching exercises on heart rate variability in patients with persistent or recurrent neck pain: a randomized controlled trial. *Chiropractic & Manual Therapies, 29*, 1-13.
15. Terzulli, C., Gironès, X., Yu, Z., Krzyzanowska, A., Puetz, V., Lombardero, N., et al. (2022). Effect of virtual reality hypnosis on pain threshold and neurophysiological and autonomic biomarkers in healthy volunteers: prospective randomized crossover study. *Journal of Medical Internet Research, 24*(7).
16. Alshami AM. Pain: is it all in the brain or the heart?. Current Pain and Headache Reports. 2019 Dec;23:1-4.
17. So V, Balanaser M, Klar G, Leitch J, McGillion M, Devereaux PJ, Arellano R, Parlow J, Gilron I. Scoping review of the association between postsurgical pain and heart rate variability parameters. Pain Reports. 2021 Dec 1;6(4):e977.
18. Lavanga M, Bollen B, Caicedo A, Dereymaeker A, Jansen K, Ortibus E, Van Huffel S, Naulaers G. The effect of early procedural pain in preterm infants on the maturation of electroencephalogram and heart rate variability. Pain. 2021 May 1;162(5):1556-66.
19. Cho SH. Frequency and intensity of electrical stimulation of human sympathetic ganglia affect heart rate variability and pain threshold. Applied Sciences. 2019 Jan;9(21):4490.
20. Lentini M, Scalia J, Lebel FB, Touma F, Jhajj A, Darlington PJ, Dover G. Association between pain catastrophizing and pain and cardiovascular changes during a cold-pressor test in athletes. Journal of athletic training. 2021 May 1;56(5):473-83.
21. Sen K, Chakraborty S, Pal S. Pain-Level Detection Using Heart Rate Variability. InInternational Conference on Emerging Electronics and Automation 2022 Dec 16 (pp. 185-199). Singapore: Springer Nature Singapore.
22. Goldaniga G, Allegri M. Does Chronic Pain Affect Heart Function?. Brain and Heart Dynamics. 2020:671-9.
23. Elhakeem RF, Lutfi MF, Ali AB, Sukkar MY. Can short-term heart rate variability predict coronary artery disease in patients undergoing elective coronary angiography due to typical chest pain?. Journal of clinical and translational research. 2020 Aug 8;6(2):66.

24. Novaković M, Krevel B, Rajkovič U, Cuderman TV, Trontelj KJ, Fras Z, Jug B. Moderate-pain versus pain-free exercise, walking capacity, and cardiovascular health in patients with peripheral artery disease. Journal of vascular surgery. 2019 Jul 1;70(1):148-56.
25. McInnis PM, Braund TA, Chua ZK, Kozlowska K. Stress-system activation in children with chronic pain: a focus for clinical intervention. Clinical child psychology and psychiatry. 2020 Jan;25(1):78-97.