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Heart rate variability responses to instrument-assisted atlas (C1) chiropractic manipulation: A randomized placebo-controlled trial

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ABSTRACT

Introduction: Musculoskeletal pain is often linked to dysfunctions of the ANS. Instrument-assisted chiropractic manipulation is promising for modulating HRV through the ANS.
Objective: To assess the impact of chiropractic manipulation on HRV in individuals with musculoskeletal pain compared to a placebo.
Methods: A randomized clinical trial included 64 participants aged 18–60 years (mean age = 32 ± 10.4) with acute or chronic musculoskeletal pain. The intervention group (IG) received a single high-velocity, low-amplitude impulse on the bilateral transverse processes of C1, while the control group (CG) received a placebo. HRV was recorded both pre- and post-intervention using a Polar H10 monitor and analyzed with Kubios HRV Standard (v3.5.0). Analysis was through repeated-measures ANOVA ($p < 0.05$).
Results: The IG showed a significant LF/HF change ($p = 0.013$), and the CG had a significant SD1/SD2 change ($p = 0.02$) in intra-group comparisons. No significant differences were found between IG and CG for variables such as SDNN, NN50, PNN50 %, SD1, SD2, LF/HF, and SD1/SD2.
Discussion: Both interventions induced HRV changes without significant intergroup differences, suggesting uncontrolled factors may influence the autonomic response.
Conclusion: Instrument-assisted chiropractic manipulation of C1 did not significantly change HRV vs. placebo, indicating the need for further studies on external variables.

1. Introduction

Musculoskeletal pain is a multifactorial condition highly prevalent globally (de et al., 2013; Lopes et al., 2014; Catai et al., 2020a; Schug et al., 2019; Reis and Nogueira, 2018; Cohen, 2015). Its interaction with the Autonomic Nervous System (ANS) is receiving growing research attention. The ANS, comprising the sympathetic and parasympathetic divisions, integrates internal and external stimuli to produce adaptive responses (de et al., 2013; Lopes et al., 2014; Catai et al., 2020b). Heart Rate Variability (HRV) analysis is a non-invasive method for assessing autonomic function, proving sensitive in detecting autonomic dysfunction and useful in cardiovascular risk stratification (de et al., 2013; Lopes et al., 2014; Catai et al., 2020a).

Manual therapy techniques, including chiropractic care with instrument-assisted methods, are gaining recognition for their potential to modulate ANS responses (Silvestrino et al.; Fuhr and Menke, 2005; Keller et al., 1999). The upper cervical region, particularly the atlas (C1), is often manipulated not to correct alignment but to stimulate the superior cervical sympathetic ganglion (SCSG) due to its anatomical proximity to C1 (Thompson, 2012).

This study employed a standardized bilateral protocol to apply instrument-assisted chiropractic manipulation, allowing controlled analysis of its potential autonomic effects on HRV. We hypothesized that such stimulation might induce measurable autonomic responses, as reflected in changes to HRV parameters.

Therefore, we aimed to evaluate the effects of bilateral instrument-

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assisted chiropractic manipulation at the atlas level on HRV in individuals with musculoskeletal pain compared to a placebo stimulus in a randomized clinical trial.

2. Methods

2.1. Study design

This is an experimental before-and-after study comparing two groups: an instrumental chiropractic intervention group and a sham group. The methodology is described according to the TIDieR (Template for Intervention Description and Replication) checklist (23). Although the study has a controlled structure, it does not qualify as a randomized clinical trial per ICMJE guidelines due to the absence of randomization by blocks or blinding of all evaluators. Therefore, the clinical trial was not registered in public trial registries. The project was approved by the Research Ethics Committee of the Augusto Motta University Center under the number CAAE: 68284323.4.0000.5235. And parecer number: 5.972.597.

2.1.1. Population

The research volunteers were invited through newsletters on digital social networks and advertisements at the physiotherapy school clinic. Individuals with musculoskeletal pain, of both sexes, between 18 and 60 years, were recruited. It was excluded: Individuals with a history of neoplasia in the last year; undergoing cancer treatment; with any neurological pathology or rheumatic conditions; Individuals with cardiac pacemaker, cardiac arrhythmia, or transplanted heart; with any cardiovascular medication; Patients who have ingested caffeine-containing foods and beverages on the day of the experiment; Individuals who have consumed alcoholic drinks in the last 24 h; Individuals who have practiced physical activity on the day of the experiment.

The sample size calculation showed the need to include 32 participants in each group. The calculation was performed using the G*Power 3.1 software and considered a power of 80 %, an error of 0.05, and an effect size of 0.3 for the proposed intervention, as reported by Vidinha et al. (2018) (Rodrigues et al., 2018).

2.1.2. Procedures and measurement instruments

The study employed electronic randomization to divide 64 individuals into two groups. The list was generated by dividing a sequence of numbers from 1 to 64 equally into two groups (A and B). Each participant was placed and evaluated on the list, starting from number 1, in the order of their entry, and so on, up to number 64. The order of the groups was: Chiropractic Instrumental Therapy (group A) and sham (group B). One evaluator screened and allocated participants to the Intervention Group (IG) or the Control Group (CG), while another assessed HRV and executed the technique in both groups. The researcher who performed the assessments and intervention has 4 years of clinical experience in the field of musculoskeletal rehabilitation and the use of chiropractic techniques.

Initially, the evaluator 1 (responsible for allocating participants to the groups) collected sociodemographic data, pain intensity, the short version of the IPAQ questionnaire, and central sensitization signs for sample characterization. To quantify pain intensity, the numerical pain rating scale (NPRS) was used, ranging from 0 (no pain) to 10 (most intense pain) (Thompson, 2012). The IPAQ short version questionnaire was also applied to assess the physical activity level of the participants (Rodrigues et al., 2018). The Central Sensitization Inventory (CSI) was also used to identify signs of central sensitization in the sample. The questionnaire has already been cross-culturally validated for Brazil (Vanderlei et al., 2009).

Then, the participant was taken to another room, where the heart rate variability was assessed by evaluator 2 (who was blinded). This examiner didn't know in which group the participant was allocated. The participant should remain lying on the stretcher for 5 min, and HRV monitoring was performed for 5 min uninterruptedly (Huang et al., 2024) using the Polar strap (model H10) attached to the chest (Terrace et al., 1996). The heart rate meter remained thoroughly moistened during the measures. If the patient had hair in the area where the strap was positioned, it was removed to avoid compromising the signal (Sillevis et al., 2010). The HRV measures before and after interventions followed the same procedures in both groups (GI and Control).

The measurement was performed in the supine position with the patient on a stretcher. During data collection, the patient was instructed to remain still and not speak as long as possible. All measurements were immediately sent to the researcher's email, including the time, data, name, weight, and height of the volunteer, to ensure that no data was lost.

The data recorded by the heart rate monitor were exported to the KubiusStandart HRV application. The following HRV variables will be analyzed: SDNN, RMSSD, pNN50, LF, HF, HF/LF, SD1, SD2, and the SD1/SD2 ratio. Table 1 shows the definitions and purposes of each variable.

The study was carried out in a controlled environment, free of large noises, with a temperature between 22 and 25 °C, with a stable internet signal, and in a private place for the physiotherapist and the participant. All patients received prior instructions on how the evaluation and treatment protocol would be performed. Box 1 shows the HRV parameters collected.

2.1.3. Intervention protocol

After the HRV measurement was completed, the intervention (IG) was performed by evaluator 3, who applied instrumental chiropractic stimulation bilaterally to the transverse processes of C1. A single stimulus was applied on the right side and another on the left side of the transverse process of C1, using Instrumental Chiropractic Therapy (ICT). The device was validated in Brazil by the Livta Institute. The clinician must manually activate this instrument and exert light pressure on the patient's skin. It is a brief, low-intensity mechanical stimulus. The device was positioned at pressure level 1 - a pragmatic clinical approach.

The intervention in the control group (evaluator 3) consisted of simulating the manipulation. The device was positioned on the transverse process of the atlas, while another device in the hand of evaluator 3 made only an audible noise. The simulation was performed bilaterally at the level of C1, without any pressure on the volunteer's skin. HRV measurements were performed before and after the simulated procedure, following the same pattern as in IG.

Table 1
Sociodemographic and clinical characteristics of participants with musculoskeletal pain (n = 64).

VARIABLES	GROUP 1(n = 32)	GROUP 2(n = 32)	P value
Age			0.63
(mean SD)	33.30 (9.30)	32.03 (9.58)	
BMI	25.90 (4.70)	28.36 (6.12)	0.05
Sex			0.19
Female	23 (72.00 %)	18 (56.00 %)	
Male	9 (28.00 %)	14 (43.00 %)	
IPAQ			0.17
1	11 (34.40 %)	13 (40.60 %)	
2	20 (62.50 %)	14(43.80 %)	
3	1 (3.10 %)	5 (15.60 %)	
CSI Part A	33.88 (14.10)	36.09 (14.88)	0.59
CSI Part B			
0	18 (56.20 %)	19 (59.40 %)	0.80
1	14 (43.80 %)	13 (40.60 %)	
NPRS	5.88 (2.21)	5.66 (1.95)	0.69

Legend: SD: standard deviation; CSI: Central Sensitization Inventory, zero does not have a diagnosis of CSI, 1 has a diagnosis of CSI; IPAC: International Physical Activity Questionnaire, 1 Irregularly active, 2 Active, 3 Very active; NPRS: Numeric Pain Ration Scale. BMI: Body mass index.

Box 1
Measures of heart rate variability variables domain

Variables	Definition	Autonomous influence	Reference value
Temporal Domain			
SDNN	Standard deviation of all normal IRRs recorded in a time interval (ms)	Sympathetic and parasympathetic	141 ± 39ms
RMSSD	Root square of the mean square of the differences between adjacent normal IRRs, over a time interval (ms)	Sympatho-vagal with parasympathetic predominance	27 ± 12
pNN50	Percentage of adjacent IRR with duration differences greater than 50 ms	parasympathetic	>7 %
Frequency Domain			
HF	High-frequency component ranging from 0.15 to 0.4 Hz	Indicating the action of the vagus nerve on the heart	975 ± 203
LF	Low-frequency component ranging from 0.04 to 0.15 Hz	Predominantly sympathetic and parasympathetic	1170 ±416m^2
LF/HF	LF and HF ratio	sympatho-vagal balance	1.5–2.0
SD1	Standard deviation parasympathetic in the short term	Represents parasympathetic modulation	>8ms
SD2	Standard deviation sympathetic in the long term	Represents sympathetic modulation	>20ms
SD1/SD2	Ratio SD1 and SD2	sympatho-vagal balance	>1ms

Reference: Task Force Test (1996) and Vanderlei (2009) (Keller et al., 1999; Vanderlei et al., 2009; Huang et al., 2024; Terrace et al., 1996).

Immediately after the techniques, HRV was measured again following the same procedures as the initial measurement (by evaluator 2).

Although clinical practice typically applies unilateral corrections based on biomechanical findings, bilateral stimulation was chosen in this study to isolate the autonomic response of the upper cervical spine, regardless of biomechanical asymmetries, ensuring methodological uniformity.

2.1.4. Data analysis

Normality was tested using the Shapiro-Wilk test. Continuous variables were described as means and standard deviations, while categorical variables were presented as absolute frequencies and percentages.

To analyze the effect of the intervention, a two-way repeated measures ANOVA was used with factors group (intervention vs. control) and time (pre vs. post-intervention). The primary analysis focused on the interaction between group and time, which indicates whether the intervention had a differential effect compared to the control. Tukey's post hoc test was used for multiple comparisons. Analyses were performed using JASP software (version 0.18.1, 2022).

3. Results

The study included 64 participants, all of whom completed all stages. The sample consisted predominantly of women (64 %), with a mean age of 32 years (SD 9.3) for the population. Some comorbidities were observed in the population (49 %), such as migraine or tension headaches, fibromyalgia, Temporomandibular Joint Disorder, Anxiety Crisis or Panic Syndrome, and Depression. The main characteristics of the sample are presented in Table 1.

Initially, intragroup analyses within the Intervention Group (IG) revealed significant changes; however, comparative studies between the intervention and control groups showed no significant differences in HRV variables, as shown in Table 2. Specifically, there were no substantial shifts in variables such as SDNN, NN50, PNN50 %, SD1, SD2, LF/HF index, or SD1/SD2 ratio between groups, as detailed by the statistical parameters F and p-values.

Comparing the sociodemographic and other specific characteristics of both groups no significant differences were found (Table 1).

After carrying out repeated measures analysis of variance (ANOVA) for each of the HRV variables and post-hoc test, although intragroup differences were found (in the IG) (Table 2), there was no significant difference in the comparison between groups.

The comparison between groups revealed that there was no significant difference for any of the following variables: SDNN - F(62.1) = 0.004, p = 0.948; NN50 – F(62,1) = 0.241, p = 0.625; NN50 % –F(62,1) = 0.168, p = 0.684,η^2 = 0.003; SD1- F(62,1) = 0.019, p = 0.890; SD2 - F (62,1) = 0.022, p = 0.881; LF/HF index - F (62.1) = 0.163; p = 0.688, η^2 = 0.002; SD1/SD2 –F(62,1) = 0.025, p = 0.875, η^2 = 0.002.

Following these analyses, while intragroup modifications signify potential internal group responses among treated individuals, no significant intergroup disparities were noted.

Table 2
Comparison of intragroup means before and after the intervention.

	Within Group Comparison					
Variáveis	G1 n = 32			G2 n = 32		
	Before	After	p-value	Before	After	p-value
SDNN						
average (sd)	43.38 (22.40)	44.45 (25.90)	0.79	43.13 (21.00)	43.98 (21.50)	0.86
NN50						
average (sd)	59.41 (64.80)	59.59 (66.60)	0.67	68.47 (61.30)	65.78 (59.50)	0.16
PNN50 %						
Average (sd)	18.92 (21.70)	19.63 (22.50)	0.65	21.61 (20.40)	21.23 (20.50)	0.14
SD1						
average (sd)	33.68 (21.20)	33.62 (24.20)	0.93	33.07 (19.70)	32.79 (20.00)	0.46
SD2						
average (sd)	50.68 (24.90)	52.49 (28.60)	0.52	50.29 (23.30)	52.56 (24.20)	0.36
LF/HF						
average (sd)	1.65 (1.40)	2.27 (2.30)	0.01	1.64 (1.60)	1.95 (1.70)	0.15
SD1/SD2						
average (sd)	1.69 (0.50)	1.75 (0.50)	0.47	1.67 (0.50)	1.80 (0.40)	0.02

4. Discussion

The findings of this randomized clinical trial suggest that cervical spinal manipulation may induce acute changes in autonomic regulation, as indicated by the significant reduction in the LF/HF ratio in the intervention group. This shift suggests a potential increase in parasympathetic activity or a decrease in sympathetic dominance following the intervention. The control group, in turn, exhibited a significant change in the SD1/SD2 ratio, although this measure is less frequently linked to direct clinical interpretations in the context of autonomic function. Importantly, no statistically significant differences were observed between the groups across all variables, which limits the strength of conclusions regarding the specific efficacy of the spinal manipulation intervention.

These results partially reflect findings in the existing literature. Sillevis et al. (2010) and Picchiottino et al. (2020), for example, also found no significant between-group differences in autonomic outcomes following thoracic spinal manipulation, reinforcing the idea that immediate autonomic responses to manipulation may be subtle or influenced by individual variability (Sillevis et al., 2010; Picchiottino et al., 2020). This suggests that, although manipulation may affect heart rate variability (HRV) parameters, its acute impact on autonomic balance may not be consistently detectable across all populations or study designs.

In contrast, other studies have reported more pronounced effects. Budgell (2001) observed significant changes in LF and HF components following upper cervical manipulation in healthy participants (Budgell and Hirano, 2001). The discrepancy between their findings and ours may be explained by the differing sample characteristics. While they evaluated asymptomatic individuals, our study involved patients experiencing musculoskeletal pain, which may affect baseline autonomic tone and responsiveness. This distinction is particularly relevant, given that chronic pain has been associated with increased sympathetic activity and altered autonomic function (Budgell and Hirano, 2001).

Supporting this hypothesis, Santos-de-Araújo et al. (2019) showed that pain intensity, disability, and catastrophic thinking were moderately correlated with reduced HRV and increased sympathetic dominance, suggesting that psychological and clinical factors can modulate autonomic responses (Santos-de- et al., 2019). Similarly, Win et al. (2015) demonstrated that autonomic outcomes varied depending on the cervical segment manipulated and whether the participant had neck pain, with parasympathetic effects more prominent in upper cervical manipulation and sympathetic inhibition observed in symptomatic individuals (Win et al., 2015). La Touche et al. (2012) also reported a sympatho-excitatory response after upper cervical mobilization, further supporting the segment-dependent nature of the autonomic effects (La et al., 2009).

In conclusion, our study indicates that spinal manipulation did not produce significant changes in autonomic parameters between groups in a symptomatic population. This suggests that the acute effects observed may not be impactful enough to distinguish between the treatment and placebo groups. Variability in individual responses and factors such as pain status and psychological profiles should be considered when interpreting these findings. Additionally, the lack of long-term follow-up restricts our understanding of potential sustained autonomic changes.

4.1. Limitations

This study evaluated only the immediate effects of cervical spinal manipulation, which may limit the understanding of longer-term autonomic responses. However, the originality of the design and the contribution regarding the pragmatic chiropractic approach should be highlighted. These findings can inform clinical practice and encourage further research to explore both immediate and long-term autonomic responses to spinal manipulation.

5. Conclusion

Instrument-assisted chiropractic manipulation applied to the C1 vertebra did not produce statistically significant changes in heart rate variability when compared to a placebo in young adults with musculoskeletal pain. In this sample, the proposed intervention was not effective in modifying HRV or influencing the assessed autonomic nervous system parameters.

CRediT authorship contribution statement

Thais de Souza Horsth: Conceptualization. **Ivan de Araujo Barros:** Investigation. **Rafael Cotta de Souza:** Investigation. **Arthur de Sá Ferreira:** Software. **Renato Santos de Almeida:** Supervision.

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work, the author(s) used Inner. ai with caution, solely to improve language and readability. After using this tool/service, the author(s) reviewed and edited the content as needed and take full responsibility for the content of the publication.

Declaration of competing interest

There were no conflicts of interest.

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References

Budgell, B., Hirano, F., 2001. Innocuous mechanical stimulation of the neck and alterations in heart-rate variability in healthy young adults. In: Autonomic Neuroscience: Basic and Clinical, 91 [Internet]. www.elsevier.comrlocaterautneu.

Catai, A.M., Pastre, C.M., Godoy, MF de, da, Silva E., Takahashi, AC. de M., Vanderlei, L. C.M., 2020a. Heart rate variability: are you using it properly? Standardisation checklist of procedures. Braz J Phys Ther [Internet] 24 (2), 91–102. https://doi.org/10.1016/j.bjpt.2019.02.006.

Catai, A.M., Pastre, C.M., Godoy, MF de, da, Silva E., Takahashi, AC. de M., Vanderlei, L. C.M., 2020b. Heart rate variability: are you using it properly? Standardisation checklist of procedures. Braz. J. Phys. Ther. 24 (2), 91–102.

Cohen, S.P., 2015. Epidemiology, diagnosis, and treatment of neck pain. Mayo Clin Proc [Internet] 90 (2), 284–299. https://doi.org/10.1016/j.mayocp.2014.09.008.

de Sá, J.C.F., Costa, E.C., da Silva, E., Azevedo, G.D., 2013. Variabilidade da frequência cardíaca como método de avaliação do sistema nervosa autônomo na síndrome dos ovários policísticos. Rev. Bras. Ginecol. Obstet. 35 (9), 421–426.

Fuhr, A.W., Menke, J.M., 2005. Status of activator methods chiropractic technique, theory, and practice. J. Manip. Physiol. Ther. 28 (2).

Huang, M., Shah, A.J., Lampert, R., Bliwise, D.L., Johnson, D.A., Clifford, G.D., et al., 2024. Heart rate variability, deceleration capacity of heart rate, and death: a veteran twins study. J. Am. Heart Assoc. 13 (7).

Keller, T.S., Colloca, C.J., Fuhr, A.W., 1999. Validation of the force and frequency characteristics of the activator adjusting instrument: effectiveness as a mechanical impedance measurement tool. J. Manip. Physiol. Ther. 22 (2), 75–86.

La Touche, R., Fernández-De-Las-Peñas, C., Fernández-Carnero, J., Escalante, K., Angulo-Díaz-Parreño, S., Paris-Alemany, A., et al., 2009. The effects of manual therapy and exercise directed at the cervical spine on pain and pressure pain sensitivity in patients with myofascial temporomandibular disorders. J. Oral Rehabil. 36 (9), 644–652.

Lopes, P., Oliveira, M., André, S., Nascimento, D., Silva, C., Rebouças, G., et al., 2014. Aplicabilidade Clínica da Variabilidade da Frequência Cardíaca. Revista Neurociências. 21 (4), 600–603.

Picchiottino, M., Honoré, M., Leboeuf-Yde, C., Gagey, O., Cottin, F., Hallman, D.M., 2020. The effect of a single spinal manipulation on cardiovascular autonomic activity and the relationship to pressure pain threshold: a randomized, cross-over, sham-controlled trial. Chiropr. Man. Ther. 28 (1), 1–16.

Reis, F., Nogueira, L., 2018. Pacientes Com Sistema Inibitório Nociceptivo Descendente Prejudicado Apresentam Controle Vagal Cardíaco Alterado Em Repouso, pp. 409–418.

Rodrigues, P., Corrêa, L., Ribeiro, M., Silva, B., Reis, F., Nogueira, L., 2018. Patients with impaired descending nociceptive inhibitory system present altered cardiac vagal control at rest. Pain Physician 21 (4), E409–E418.

Santos-de-Araújo, A.D., Dibai-Filho, A.V., dos Santos, S.N., de Alcântara, E.V., Souza, C. da S., Gomes, C., et al., 2019. Correlation between chronic neck pain and heart rate variability indices at rest: a cross-sectional study. J Manipulative Physiol Ther [Internet] 42 (4), 219–226. https://doi.org/10.1016/j.jmpt.2018.11.010.

Schug, S.A., Lavand'Homme, P., Barke, A., Korwisi, B., Rief, W., Treede, R.D., 2019. The IASP classification of chronic pain for ICD-11: chronic postsurgical or posttraumatic pain. Pain 160 (1), 45–52.

Sillevis, R., Cleland, J., Hellman, M., Beekhuizen, K., 2010. Immediate effects of a thoracic spine thrust manipulation on the autonomic nervous system: a randomized clinical trial. J. Man. Manip. Ther. 18 (4), 181–190.

Silvestrino D, Camargo JV de, Depintor JDP, Lopes ESM. Efetividade e eficácia do Método Ativador® e do instrumento Activator - Análise crítica da literatura. brasilian journal of Chiropractic. volume III(2):118–130.

Terrace, C., Unido, R., Cardiologia, SE De, 1996. Diretrizes, pp. 354–381.

Thompson, J.C., 2012. Netter Atlas De Anatomia Ortopédica [Internet]. Elsevier Health Sciences Brazil, p. 416. https://books.google.com/books?id=2nnqhWqHNAkC&pgis=1.

Vanderlei, L.C.M., Pastre, C.M., Hoshi, R.A., Carvalho, TD de, Godoy, MF de, 2009. Noções básicas de variabilidade da frequência cardíaca e sua aplicabilidade clínica. Rev. Bras. Cir. Cardiovasc. 24 (2), 205–217.

Win, N.N., Jorgensen, A.M.S., Chen, Y.S., Haneline, M.T., 2015. Effects of upper and lower cervical spinal manipulative therapy on blood pressure and heart rate variability in volunteers and patients with neck pain: a randomized controlled, cross-over, preliminary study. J Chiropr Med 14 (1), 1–9. https://doi.org/10.1016/j.jcm.2014.12.005 [Internet].