ARTICULO ORIGINAL

EXPLORACIÓN DE LAS OSCILACIONES ELECTROENCEFALOGRÁFICAS DURANTE LA COHERENCIA CARDIÁCA EN INDIVIDUOS SANOS

ELECTROENCEPHALOGRAPHIC CORRELATES OF HEARTH COHERENCE IN HEALTHY INDIVIDUALS

CORRELATOS ELETROENCEFALOGRÁFICOS DA COERÊNCIA CARDÍACA EM INDIVÍDUOS SAUDÁVEIS

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Resumen

Este estudio explora las oscilaciones electroencefalográficas (EEG) durante la coherencia cardíaca en individuos sanos, con el objetivo de abordar la falta de datos empíricos en esta área. Las posibles aplicaciones para estrategias terapéuticas en la ansiedad y la depresión subrayan la importancia de comprender las características del EEG durante la coherencia cardíaca.

Métodos:

Realizado como un estudio transversal comprensivo, descriptivo y exploratorio, los participantes fueron sometidos a una intervención multifacética. Inicialmente, la caracterización sociodemográfica proporcionó contexto. Se emplearon pruebas psicométricas para medir parámetros psicológicos, mientras que el análisis de la señal EEG se centró en variables clave, incluyendo asimetría alfa frontal, potencia absoluta de theta frontal, potencia absoluta de beta frontal, potencia absoluta de alfa frontal y potencia absoluta de theta frontal. Los participantes fueron evaluados tanto antes como después de implementar la coherencia cardíaca, con un énfasis especial en explorar posibles aplicaciones de neuroretroalimentación.

En la intervención, los participantes se involucraron en la técnica del "Entrenador de Coherencia", que implica la modulación controlada de la frecuencia respiratoria para inducir la coherencia cardíaca. Esta técnica es reconocida por su eficacia en fomentar la regulación emocional. Las aplicaciones de neuroretroalimentación tenían como objetivo modular parámetros de EEG, potencialmente influyendo en el bienestar emocional y mental.

Resultados:
Inscribiendo participantes con diversas características demográficas, el estudio descubrió correlaciones significativas, especialmente entre los niveles de coherencia con los ojos cerrados y la potencia frontal absoluta de theta con los ojos cerrados. Las pruebas de Wilcoxon demostraron diferencias estadísticamente significativas pre y post-intervención en los niveles de coherencia, puntuaciones de ansiedad y asimetría beta frontal.

Conclusión:
Los resultados del estudio sugieren intervenciones potenciales de neuroretroalimentación, especialmente en el contexto de la técnica del "Entrenador de Coherencia", que no solo resultó efectiva en mitigar los síntomas de ansiedad, sino que también iluminó direcciones prometedoras para futuras aplicaciones de neuroretroalimentación.

Palabras clave: Coherencia Cardíaca, Características del EEG, Intervenciones Terapéuticas, Estado Socioeconómico, Ansiedad, Salud Mental Preventiva.

Abstract

This study delves into the electroencephalographic (EEG) oscillations during heart coherence in healthy individuals, aiming to address the dearth of empirical data in this area. The potential applications for therapeutic strategies in anxiety and depression underscore the significance of understanding EEG characteristics during heart coherence.

Methods:

Conducted as a comprehensive, descriptive, exploratory cross-sectional study, participants underwent a multi-faceted intervention. Initially, socio-demographic characterization provided context. Psychometric testing was employed to gauge psychological parameters, while EEG signal analysis focused on key variables, encompassing frontal alpha asymmetry, absolute frontal theta power, absolute frontal beta power, absolute frontal alpha power, and absolute frontal theta power. The participants were assessed both before and after implementing heart coherence, with a special emphasis on exploring potential neurofeedback applications.

In the intervention, participants engaged in the "Coherence Coach" technique, involving controlled modulation of respiratory frequency to induce heart coherence. This technique is recognized for its efficacy in fostering emotional regulation. Neurofeedback applications aimed to modulate EEG parameters, potentially influencing emotional and mental well-being.

Results:

Enrolling participants with diverse demographics, the study uncovered significant correlations, notably between coherence levels with closed eyes and absolute frontal theta power with closed eyes. Wilcoxon tests demonstrated statistically significant pre- and post-intervention differences in coherence levels, anxiety scores, and frontal beta asymmetry.

Conclusion:

The study's outcomes suggest potential neurofeedback interventions, especially in the context of the "Coherence Coach" technique, which not only proved effective in mitigating anxiety symptoms but also illuminated promising directions for future neurofeedback applications.

Keywords: Heart Coherence, EEG Characteristics, Therapeutic Interventions, Socioeconomic Status, Anxiety, Preventive Mental Health.

Resumo

Este estudo explora as oscilações eletroencefalográficas (EEG) durante a coerência cardíaca em indivíduos saudáveis, com o objetivo de abordar a falta de dados empíricos nesta área. As possíveis aplicações para estratégias terapêuticas na ansiedade e na

depressão destacam a importância de compreender as características do EEG durante a coerência cardíaca.
Métodos:
Realizado como um estudo transversal compreensivo, descritivo e exploratório, os participantes foram submetidos a uma intervenção multifacetada. Inicialmente, a caracterização sociodemográfica forneceu contexto. Foram utilizados testes psicométricos para medir parâmetros psicológicos, enquanto a análise do sinal EEG focou em variáveis-chave, incluindo assimetria alfa frontal, potência absoluta de theta frontal, potência absoluta de beta frontal, potência absoluta de alfa frontal e potência absoluta de theta frontal. Os participantes foram avaliados tanto antes quanto depois de implementar a coerência cardíaca, com ênfase especial em explorar possíveis aplicações de neurofeedback.
Na intervenção, os participantes se envolveram na técnica do "Treinador de Coerência", que envolve a modulação controlada da frequência respiratória para induzir a coerência cardíaca. Esta técnica é reconhecida por sua eficácia em promover a regulação emocional. As aplicações de neurofeedback tinham como objetivo modular parâmetros do EEG, potencialmente influenciando o bem-estar emocional e mental.
Resultados:
Inscrição de participantes com diversas características demográficas, o estudo descobriu correlações significativas, especialmente entre os níveis de coerência com os olhos fechados e a potência frontal absoluta de theta com os olhos fechados. Os testes de Wilcoxon demonstraram diferenças estatisticamente significativas pré e pós-intervenção nos níveis de coerência, pontuações de ansiedade e assimetria beta frontal.
Conclusão:
Os resultados do estudo sugerem intervenções potenciais de neurofeedback, especialmente no contexto da técnica do "Treinador de Coerência", que não só se mostrou eficaz na redução dos sintomas de ansiedade, mas também iluminou direções promissoras para futuras aplicações de neurofeedback.

Palavras-chave: Coerência Cardíaca, Características do EEG, Intervenções Terapêuticas, Status Socioeconômico, Ansiedade, Saúde Mental Preventiva.

Introduction:

The pursuit of optimal health and well-being has driven the exploration of innovative methodologies that bridge the realms of physiological and psychological functioning. This research embarks on a journey to unravel the intricate interplay between heart coherence, as a marker of autonomic nervous system efficiency, and electroencephalographic (EEG) oscillations, delving into uncharted territories within the Colombian population, specifically in Pereira. While the effects of heart coherence on emotional regulation and cognitive function have been documented, the nexus between this coherence and EEG patterns remains an evolving realm of investigation.

Heart Coherence

At the core of this study lies the concept of heart coherence, a distinctive pattern in heart rate variability associated with enhanced autonomic nervous system function, emotional stability, and optimized overall cognitive and physiological performance (Lehrer & Gevirtz, 2014). Characterized by a harmonious, sinusoidal-like waveform, a coherent heart rhythm exhibits a narrow, high-amplitude peak in the low-frequency region, typically around 0.1 Hz, without significant peaks in other bands (see Figure 1). Achieving heart coherence often involves specific breathing techniques, fostering rhythmic and deep breathing at a defined frequency, synchronizing the respiratory rhythm with the heart rate (McCraty & Shaffer, 2015). Scientific literature has reported various benefits of heart coherence, including the alleviation of anxiety, depression, and sleep disorders (Gevirtz, 2013).

Heart coherence assessment involves identifying the peak within the 0.04 to 0.26 Hz range of the heart rate variability power spectrum, calculating the integral within a 0.030 Hz window centered on that peak, and determining the total power of the entire spectrum. The coherence ratio is then formulated as (Peak Power/[Total Power - Peak Power]) (McCraty, 2017). The Emwave Pro software, developed by HeartMath, yields an average coherence score ranging from 0 to 16, reflecting diverse levels of coherence.

The heart coherence journey leads to the synchronization of respiratory and cardiac rhythms, underpinning its positive impacts on emotional and physiological states. Notably, individuals experiencing coherent heart rhythms have reported reduced symptoms of anxiety, depression, and improved sleep quality (Gevirtz, 2013).

Hearth rate variability

In tandem with heart coherence, the variability of heart rate (HRV) emerges as a crucial indicator of autonomic nervous system functionality. Defined as the variation in time between heartbeats, expressed in milliseconds, HRV holds significant implications for cardiovascular health and mortality risk. Reduced HRV has been associated with an elevated risk of cardiovascular events, with a 32% to 45% increase in the risk of a first cardiovascular event in populations without known cardiovascular disease (Hillebrand, 2013).

Electroencephalogram (EEG)

In the field of neural exploration, the electroencephalogram (EEG) takes center stage as a non-invasive technique capturing the brain's electrical activity. Positioned on the scalp, electrodes could assess absolute power, synchrony, asymmetry, coherence, and functional connectivity.

This research delves into the topic of EEG parameters, including frontal alpha asymmetry, frontal alpha absolute power, frontal beta absolute power, frontal theta absolute power, and frontal beta asymmetry. These indices unfold layers of information regarding emotional regulation, cognitive processes, and overall brain function.

Background

In the Colombian landscape, the exploration of heart coherence's application and its impact on EEG oscillations is yet to be undertaken. However, beyond the borders, a plethora of studies in diverse populations have unearthed the efficacy of heart coherence techniques. By employing methodologies like biofeedback, mindfulness meditation, or specific frequency training, researchers have probed the intricate relationship between heart coherence and EEG oscillations, unraveling multifaceted parameters such as spectral power, interhemispheric coherence, and cortico-muscular coherence.

Illustrative studies offer glimpses into the potential of heart coherence to modulate neural oscillations and influence mental well-being. Balconi et al. (2021) hint at increased alpha and beta power in EEG, suggesting heightened cortical activation and improved emotional regulation. Krygier et al. (2019) shed light on experienced meditators exhibiting enhanced heart coherence and alpha power during mindfulness meditation, reflecting a state of conscious relaxation and alertness. Da Silva et al. (2018) reveal that heart coherence training reduces anxiety and depression symptoms, accompanied by increased interhemispheric alpha coherence, signifying improved communication between brain hemispheres. Escolano et al. (2017) demonstrate that a single session of neurofeedback training in theta increases heart coherence and theta power in EEG, implying enhancements in attention and cognitive processing. Jaros et al. (2017) unravel the complexities of heart coherence in combat veterans with post-traumatic stress disorder, exposing reduced heart coherence and delta interhemispheric coherence in EEG, indicating disturbances in emotional regulation and stress response.

Despite these strides, the underlying neurophysiological mechanisms of heart coherence beckon further exploration. Researchers such as Laptinskaya et al. (2020) and Wang et al. (2021) have delved into the connection between heart coherence and EEG in older adults and university students, adding evidence on influential factors like age, cognitive status, and stress. However, within this population, there remains a call for additional research to identify new variables, clarify the neurophysiological mechanisms underlying heart coherence, and develop interventions to enhance physical and mental well-being.

Current State of the Art

In the ambit of this specific inquiry, existing studies present compelling evidence linking heart coherence with modifications in EEG oscillations. Choi et al. (2011) scrutinized the impacts of heart coherence on EEG activity in healthy individuals, revealing increased alpha oscillations during heart coherence techniques, indicative of heightened relaxation and stress reduction.

Beyond the healthy population, investigations into the relationship between heart coherence and EEG oscillations in psychiatric patients have also yielded intriguing results. Melo et al. (2015) explored the effects of heart coherence in anxiety disorder patients, noting an increase in alpha and a decrease in beta EEG oscillations, suggesting reduced anxiety levels and heightened relaxation. Zotev et al. (2016) delved into the effects of heart coherence in patients with depression, showcasing increased alpha and decreased delta EEG oscillations, indicating a reduction in depression-associated brain activity.

In conclusion, the integration of heart coherence and EEG analyses within the Colombian context not only enriches the global understanding of these phenomena but also sets the stage for potential interventions that could revolutionize mental and physiological well-being. The synthesis of physiological and neural insights promises to unveil the intricacies of the mind-body connection and pave the way for novel approaches to holistic health. This research endeavors to contribute substantially to the burgeoning field of psychophysiological exploration, unraveling the mysteries of heart and brain coherence in the pursuit of enhanced well-being.

Methods:

This study employed a cross-sectional, exploratory, and observational design to investigate the relationship between cardiac variability and electroencephalographic patterns in a healthy population from Pereira.

A non-probabilistic convenience sampling method was utilized to select a representative group of 20 participants. The selection process considered the individuals' availability and willingness to participate in the study.

The unit of analysis involved the examination of records detailing average hearth coherence, Hamilton Anxiety scores, and electroencephalographic traces of the participants. Inclusion criteria specified residents of Pereira, both genders, aged between 18 and 80 years, and right-handed individuals who provided informed consent.

Exclusion criteria excluded individuals with a history or current diagnosis of mental disorders listed in DSM-5R, neurological or cardiovascular pathologies, any chronic pathology, recent consumption of psychoactive substances, intake of medications affecting the central nervous system in the last 48 hours, and those who were pregnant or lactating. Participants unwilling to participate or refusing to sign informed consent were also excluded.

The study encompassed a range of variables, covering demographic factors such as age, sex, occupation, education, and marital status, along with specific physiological measures related to cardiac and electroencephalographic activity.

Data collection occurred between October 20 and November 17, 2022. Participants, meeting inclusion criteria, were invited to the University Tecnológica de Pereira at the Hospital Universitario San Jorge. Prior to data collection, participants received comprehensive information about the research objectives and procedures, ensuring their voluntary participation through informed consent.

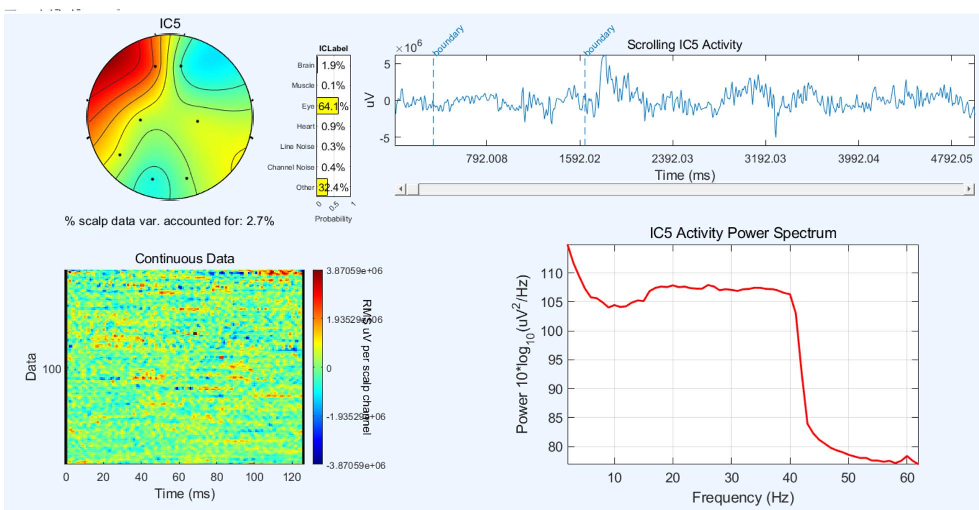
Participants completed a sociodemographic questionnaire followed by the Hamilton Anxiety Scale (HAS), adapted to Spanish, to assess anxiety levels. Subsequently, electrodes for electroencephalography (EEG) were placed on the scalp, and a heart rate variability (HRV) sensor was positioned on the left earlobe. Measurements were taken over 15 minutes, divided into eyes-closed, eyes-open, and "Coherence Coach" strategy phases. The HAS was administered again after the procedure.

Electrode placement followed the international 10/20 system, covering frontal, central, parietal, temporal, and occipital areas. Gel was applied to minimize skin resistance, ensuring impedances did not exceed 5 kΩ.

The "Coherence Coach" strategy, utilizing the EmWave Pro software from HeartMath, guided participants to synchronize breathing with real-time heart rate variability data on a monitor. Coherence was achieved when the average coherence exceeded a predefined threshold.

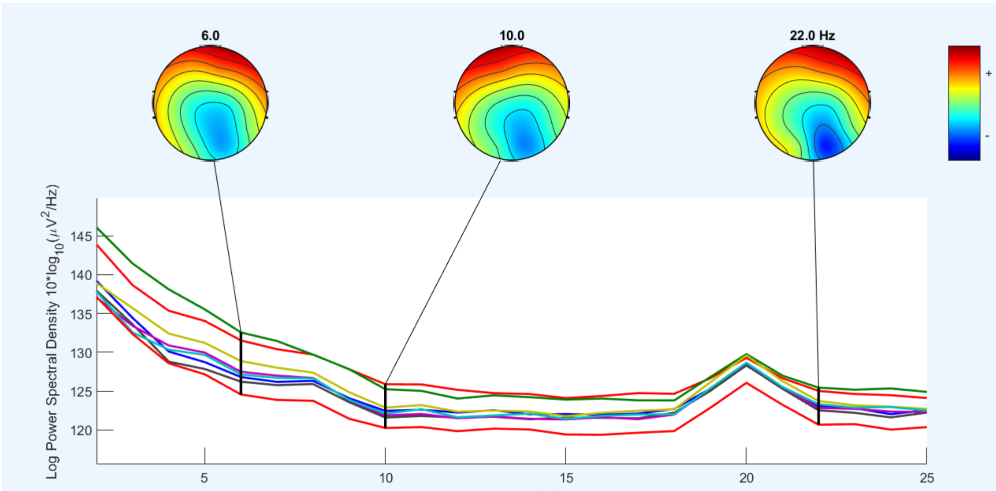
EEG data underwent preprocessing using EEGLAB, including electrode adjustment, bandpass filtering, manual artifact removal, epoch segmentation (eyes-open/eyes-closed), time-frequency analysis, and analysis of absolute powers and asymmetries in the frontal region (Fig 1)

Figure 1. *Rejected components (Ocular)*



Data processing involved transforming temporally processed EEG data into frequency domain using a 256-point fast Fourier transform Asymmetries and absolute powers were extracted using FAA and Darbeliali plugins in EEGLAB (Fig 2).

Figure 2. *Spectral Map of an EEG during Heart Coherence (Asymmetric Spectral Distribution with a Low-Amplitude Peak at 7.8 Hz - Theta and a High-Amplitude Peak at 20 Hz - Delta Band)*



The processed data were organized into a Microsoft Excel database and transferred to SPSS for analysis.

Results:

Sociodemographic Characteristics:

Participants aged 21 to 60 years were evaluated, with an average age of 29.7 years. The majority were men (65%), and 65% had undergraduate education. The most common marital status was single (80%), and most participants (55%) resided in stratum 3 (Table 1)

Table 1. *Sociodemographic aspects*

Demographic Aspects		Absolute frequency	Relative Frequency
Sex	Female	7	35%
	Male	13	65%
Education	None	0	0%
	Primary	0	0%
	High school	1	5%
	Technical	4	20%
	Undergraduate	13	65%

	Posgraduate	2	10%
Marital Status	single(a)	16	80%
	Married(a)	2	10%
	Separated (a)	2	10%
Residential Zone	1	1	5%
	2	3	15%
	3	11	55%
	4	3	15%
	5	1	5%
	6	1	5%

Outlier Analysis:

Before descriptive and comparative analysis, potential outliers were identified and corrected using the box plot method. Specific variables like "Average Coherence Eyes Closed," "Hamilton pre," and "Hamilton pos" showed outliers, which were rectified by substituting values at the respective limits.

Descriptive Analysis of Variables:

Average coherence had mean values of 0.92 with eyes open, 0.99 with eyes closed, and 3.4 during strategy implementation. Initial Hamilton Anxiety Rating Scale (HARS) score averaged 11.2, decreasing to 7.2 post-strategy. Frontal alpha asymmetry averaged 0.14 with eyes closed, 0.13 with eyes open, and 0.16 during the strategy. Frontal beta asymmetry averaged 0.15 with eyes closed, 0.2 with eyes open, and 0.51 during the strategy. Regarding power in different frequency bands, frontal theta power averaged 7.4 with eyes closed, 6.2 with eyes open, and 7.7 during coherence. Frontal alpha power had an average of 29.5 with eyes closed, 27.6 with eyes open, and 31.5 during the strategy. Finally, frontal beta power recorded an average of 40.6 with eyes closed, 38.2 with eyes open, and 30.8 during the strategy (Table 2).

Table 2. *Descriptive Statistics*

	N	Minimum	Maximum	Mean	SD
AC_CE	20	,30	1,90	,9900	,48112
ACO_OE	20	,40	1,80	,9200	,40341
AC_I	20	1,20	7,00	3,4400	1,71384
HAMILTONPRE	20	2,00	17,00	10,6000	4,33347
HAMILTONPOS	20	2,00	11,00	6,5000	2,89282
FAA_CE	20	,02	,38	,1416	,11889
FAA_OE	20	,02	,37	,1339	,10991
FAA_I	20	,02	,36	,1673	,09564
FBA_CE	20	,02	,42	,1532	,13882
FBA_OE	20	,02	,56	,2056	,16688
FBA_I	20	,06	,46	,2153	,13057
ATP_CE	20	2,30	19,60	7,4135	4,42906
ATP_OE	20	2,40	16,14	6,2600	4,10559
ATP_I	20	3,20	14,30	7,7235	3,50064
AAP_CE	20	12,24	62,27	29,5730	12,32646
AAP_OE	20	12,30	45,44	27,6835	9,24857
AAP_I	20	9,10	54,60	31,5315	14,35305
ABP_CE	20	15,60	77,80	40,6390	18,11140
ABP_OE	20	13,96	74,64	38,2475	18,95264
ABP_I	20	9,40	65,50	30,8430	16,70363

AC (Average coherence). CE (Eyes closed). OE (Eyes open) . I (intervention – “Coherence cach”) FAA (Fronal alpha asymmetry) FBA (Frontal beta asymmetry) ATP (Frontal Absolute Theta power) AAP (Frontal absolut alpha power) ABP (Frontal absolut beta power)

Correlation Analysis:

Correlations between coherence level and examined variables showed a statistically significant relationship only between average coherence with eyes closed and Absolute Theta Power with eyes closed, revealing a direct proportional association (p 0.01). Although it does not constitute a formal objective of the study, it is relevant to note the identified positive correlation between socioeconomic status and average coherence with eyes open, as well as the inversely proportional correlation between age and average coherence during the implementation of the strategy. ($p < 0.05$)

Table 3. *Correlations*

			ACCE	PATOC
Spearman Rho	ACCE	Coefficient of Correlation	1,000	,550*
		Sig. (two-tailed)	.	,012
	ATPCE	Coefficient of Correlation	,550*	1,000
		Sig. (two-tailed)	,012	.

Estr

			Age	SES	ACCE	ACOE	ACI
Rho de Spearman	Age	CC	1,000	,033	-,083	-,008	-,511
		Sig.	.	,889	,729	,973	,021
	SES	CC	,033	1,000	,291	,461	,170
		Sig.	,889	.	,214	,041	,475

	20	20	20	20	20

Comparative Analysis:

Wilcoxon tests demonstrated statistically significant differences in average coherence, HARS, and frontal beta asymmetry comparisons before and after the intervention (Table 4.) . Effect size analysis indicated large positive correlations for average coherence and HARS, medium positive correlation for frontal beta asymmetry with eyes closed, and small positive correlations for frontal alpha asymmetry regardless of eyes, absolute Theta power with eyes open, and absolute alpha power with eyes open. A small negative effect size was observed for absolute beta power (Table 5).

Table 4.: *Comparative analysis (Wilcoxon)*

	Z	Sig.
ACI - ACCE	**-3,784[b]**	**<,001**
ACI - ACOE	**-3,921[b]**	**<,001**
HAMILTONPOS - HAMILTONPRE	**-3,587[c]**	**<,001**
FAAI - FAACE	-,664[b]	,507
FAAI - FAAOE	-,896[c]	,370
FBAI - FBACE	**-2,800[b]**	**,005**
FBAI – FBAOE	-1,328[b]	,184
ATPI – ATPCE	-,672[b]	,502
ATPI – ATPOE	-1,325[b]	,185
AAPI – AAPCE	-,971[b]	,332
AAPI – AAPPE	-1,045[b]	,296
ABPI – ABPCE	-1,381[c]	,167
ABPI - ABPOE	-1,568[c]	,117

AC (Average coherence). CE (Eyes closed). OE (Eyes open) . I (intervention – "Coherence cach") FAA (Fronal alpha asymmetry) FBA (Frontal beta asymmetry) ATP (Frontal Absolute Theta power) AAP (Frontal absolut alpha power) ABP (Frontal absolut beta power)

Table 5. *Effect size*

					Confidence Interval 95%	
			Standardizer[a]	Estimation of Points	Inferior	Superior
Par 1	ACI - ACCE	Cohen´s d	1,93078	1,269	,666	1,853
		Hedges	2,01141	1,218	,639	1,779
Par 2	ACI - ACOE	Cohen´s d	1,68167	1,499	,844	2,134
		Hedges	1,75190	1,438	,811	2,049
Par 3	HAS POS - HASPRE	Cohen´s d	3,56740	-1,149	-1,709	-,571
		Hedges	3,71638	-1,103	-1,641	-,548
Par 4	FAAI – FAACE	Cohen´s d	,08660	,297	-,155	,742
		Hedges	,09022	,285	-,149	,712
Par 5	FAAI – FAAOE	Cohen´s d	,10397	,322	-,132	,768
		Hedges	,10831	,309	-,127	,737
Par 6	FBAI – FBACE	Cohen´s d	,11380	,086	-,355	,524
		Hedges	,11856	,082	-,340	,503
Par 7	FBAI – FBAOE	Cohen´s d	,09635	,645	,155	1,121
		Hedges	,10037	,619	,149	1,076
Par 8	ATPI – ATPCE	Cohen´s d	5,93393	,247	-,202	,689
		Hedges	6,18175	,237	-,194	,661
Par 9	ATPI – ATPOE	Cohen´s d	3,62759	,085	-,355	,523
		Hedges	3,77910	,082	-,341	,502

Par 10	AAPI – AAPCE	Cohen´s d	13,79197	,279	-,172	,723
		Hedges	14,36797	,268	-,165	,694
Par 11	AAP I – AAPOE	Cohen´s d	16,95266	,116	-,326	,554
		Hedges	17,66067	,111	-,313	,532
Par 12	ABP1 – ABPCE	Cohen´s d	20,05302	-,369	-,818	,089
		Hedges	20,89052	-,354	-,785	,085
Par 13	ABPI – ABPOE	Cohen´s d	25,54465	-,383	-,834	,076
		Hedges	26,61149	-,368	-,800	,073

AC (Average coherence). CE (Eyes closed). OE (Eyes open) . I (intervention – "Coherence cach") FAA (Fronal alpha asymmetry) FBA (Frontal beta asymmetry) ATP (Frontal Absolute Theta power) AAP (Frontal absolut alpha power) ABP (Frontal absolut beta power)

Discussion:

The detailed exploration of age, gender, and social stratum distilled a diverse demographic profile, ranging from an average age of 29.7 years to a notable dispersion with a mode of 23 years. The majority of males (65%) and predominance of singles (80%) added layers of complexity to the sociodemographic narrative. Education, spanning from basic high school studies to postgraduate degrees, contributed significant nuances to the fabric of the sample. While not a formal objective of the study, it is pertinent to note the identified positive correlation between socioeconomic status and average coherence with open eyes, as well as the inversely proportional correlation between age and average coherence during the strategy application.

In the analytical journey, the detection and correction of outliers through the box plot diagram, focusing on specific variables such as "average coherence with closed eyes," "Hamilton pre," and "Hamilton post," fortified the integrity and reliability of the results. Addressing outliers with caution is imperative, as their indiscriminate removal may result in the loss of substantial information or distortion of results. The chosen strategy of trimming or truncation, substituting outliers with the corresponding values at the 5th or 95th percentile, mitigates the impact of extreme values while preserving the sample size and avoiding the loss of degrees of freedom. Renowned authors like Wilcox and

Keselman (2003) advocate for this technique, asserting that trimming enhances the robustness and power of non-parametric tests.

In the assessment of normality, the selection of the Shapiro-Wilk test, determined by the sample size, revealed that while nine variables contradicted the assumption of a normal distribution, another eleven adhered to this expectation. This keen discernment laid the foundation for the transition to non-parametric analyses, a choice that would prove pivotal in the subsequent stages.

The intricate interconnection between heart coherence and brain activity began to take shape in the descriptive analyses. Average coherence, central in these data, exhibited notable values, showcasing specific variations with open and closed eyes and during the implementation of the heart coherence strategy. The significant decrease in the Hamilton Anxiety Rating Scale (HARS), dropping from 11.2 to 7.2 after the intervention, could have significant therapeutic implications.

Upon applying Spearman tests, a positive and significant correlation was found between average coherence with closed eyes and Absolute Theta Power with closed eyes. This suggests that heart coherence is associated with an increase in brain activity in the theta band at the frontal level. This finding unveils a complex and novel interaction between the heart and the brain, deserving further exploration.

Comparative analyses, executed with the precision of Wilcoxon tests, validated the effectiveness of the heart coherence strategy. The statistically significant reduction in average coherence, HARS, and frontal beta asymmetry post-intervention revealed a considerable effect size, offering not only confirmation but also valuable insights into the magnitude of the observed changes. The effect size of the strategy application on other variables such as frontal alpha asymmetry, absolute alpha power, absolute theta power, and absolute beta power was small but warrants attention.

The findings of this study suggest a positive correlation between average coherence with open eyes and socioeconomic status. This association has been previously studied in two separate investigations. Lambert et al. (2005), analyzing the repercussions of race and social position on cardiovascular outcomes, noted that both minority race and lower social status correlate with a significant decrease in heart rate variability (HRV). This phenomenon, linked to mechanisms of chronic stress not fully understood, reveals an alteration in the function of the autonomic nervous system. The results of this study contribute to a more comprehensive understanding of the factors influencing cardiovascular health in specific demographic contexts.

A study in 2021 by Van Nieuwenhuizen et al. focused on investigating the relationship between socioeconomic status (SES) and the amplitude of diurnal heart rate variations, considering it a revealing indicator of autonomic nervous system activity. Using data from 450 participants in a sub-study of HELIUS in Amsterdam, Netherlands, no solid evidence was found to support the hypothesis of a decrease in the amplitude of diurnal heart rate variations in individuals with lower socioeconomic status.

Anxiety is an emotion characterized by a state of physiological and psychological activation in response to a perceived or anticipated threat (Barlow, 2002). Anxiety can negatively impact cardiovascular function, increasing the risk of coronary disease and cardiac death (Roest et al., 2010). Additionally, anxiety can alter heart rate variability (HRV), reducing heart coherence and emotional regulation capacity (Chalmers et al., 2014).

This study found a significant relationship between average coherence (measured by HRV) and scores on the Hamilton Anxiety Rating Scale, indicating that higher coherence is associated with lower anxiety and vice versa. This finding aligns with scientific evidence suggesting that coherence is an indicator of emotional well-being and that its training can decrease stress and anxiety, as well as improve emotional intelligence and cognitive performance (Lehrer et al., 2020). Framing the analysis of this result in light of recent studies (González et al., 2015; Lebedeva et al., 2020; Cheng et al., 2020), it is possible to provide a detailed view of the complex relationships between heart coherence training, HRV, and anxiety.

This study found a statistically significant difference between frontal beta asymmetry before and after the implementation of the strategy. While no studies specifically documented frontal beta asymmetry and heart coherence, a study by Hofman et al. (2012) investigated the relationship between frontal beta oscillation asymmetry at rest and aggressive trends and behavioral inhibition in 28 healthy participants. The results suggested that frontal beta asymmetry at rest predicted aggression and behavioral inhibition independently. Participants with greater right frontal asymmetry showed higher aggression and lower behavioral inhibition, while those with greater left frontal asymmetry showed lower aggression and higher behavioral inhibition. This suggests that frontal beta asymmetry at rest reflects a neural mechanism modulating aggression and behavioral inhibition, highlighting its potential as a clinical and therapeutic parameter in future research.

The average coherence and frontal theta power with closed eyes showed a statistically significant correlation, with a directly proportional association. This finding aligns with a similar study conducted by Lee and colleagues (2022), which aimed to investigate whether HRV showed a significant correlation with electroencephalogram (EEG) during working memory performance in patients with depressive or anxiety disorders. The study concluded that HRV in patients with anxiety disorders showed a significant positive correlation with theta power in the right frontal region during the task, suggesting that HRV is related to neuronal activity associated with executive function in patients with depressive or anxiety disorders. This emphasizes the potential interplay between heart coherence, HRV, and neural activity in emotional disorders.

For alpha and beta power variables, no statistically significant findings were documented in our study, which could be related to the sample size. Further research with larger sample sizes is warranted to explore the nuances of these relationships.

Conclusions:

La Based on the findings of this research, the following relevant conclusions and recommendations are drawn:

An inversely proportional relationship exists between socioeconomic status and baseline heart coherence level. This connection gains importance considering the association of HRV with cardiovascular risk, emphasizing that social equity impacts not only mental health but also the physical health of individuals.

The "Coherence Coach" technique with a low challenge level (average coherence above 1) proves to be an effective tool in alleviating anxiety symptoms in healthy adults. This finding suggests significant implications for developing preventive programs in mental health.

Frontal beta asymmetry emerges as a statistically and possibly therapeutically interesting parameter, significantly influenced by strategy implementation. Further research in larger samples and diverse population groups could include this parameter in neurofeedback techniques.

The impact of this study extends beyond initial expectations, enabling local appropriation of generated knowledge. It can serve as a biologically grounded foundation to address social inequality in Pereira, supporting community preventive programs through coherence training campaigns in vulnerable communities. This social approach addresses both basic population needs and the reduction of physical and mental vulnerability associated with decreased HRV.

Conflictos de interés:

No se presenta conflicto de interés.

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