Article

Cardiac Coherence and the Effectiveness of Cardiovascular Biofeedback in the Nursing Team: A Randomized Clinical Trial*

* This article stems from the doctoral thesis in nursing entitled "Efeito do biofeedback cardiovascular sobre o coping da equipe de enfermagem: ensaio clínico randomizado", submitted to the Postgraduate Nursing Program of the Universidade Federal do Rio Grande do Sul, Brazil, available at: http://hdl.handle.net/10183/249381

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Theme: Healthcare technologies; coping and adapting to the state of health

Contributions to the field: The distinguishing aspect of this study is that it presents data on the effectiveness of cardiovascular biofeedback, an innovative and promising technological tool for the recovery and promotion of the psycho-emotional health of nursing professionals. Through guided deep breathing, cardiovascular biofeedback allows the development of self-awareness and self-control for respiratory modulation, in addition to promoting improved cardiac coherence and activation of the parasympathetic nervous system, which are vital for the recovery and maintenance of homeostasis and the psycho-emotional health of nursing professionals.

Abstract

Introduction: Through guided and conscious deep breathing, cardiovascular biofeedback, an innovative technological tool that enables improved cardiac coherence and activation of the parasympathetic nervous system, which are vital for recovering and maintaining homeostasis and psycho-emotional health. **Objective:** To verify the effect of cardiovascular biofeedback on heart rate variability parameters in nursing professionals. **Materials and Methods:** This is a randomized clinical trial conducted in two groups — biofeedback and placebo — with 115 nursing professionals working in clinical and surgical inpatient units at a university hospital, who presented an overall stress level higher than 1, according to the Stress Symptom Scale. The groups participated in nine appointments over three weeks. The outcome was assessed by rMSSD parameters and cardiac coherence at the end of each appointment, which were measured using EmWave Pro Plus®, which uses photoplethysmography to quantify physiological data related to the heartbeat. The analysis was performed using generalized estimation equations, considering $\alpha = 5\,\%$. **Results:** There was a significant time-group interaction in cardiac coherence parameters; the intervention group presented an increase in the mean cardiac coherence parameters at all measurement times, when compared to the control group ($p < 0.001$; $r > 0.98$). There was no significant time-group interaction in the rMSSD parameters at any of the measurement times ($p = 0.432$). As a mind-body therapy, cardiovascular biofeedback proved to be useful and promising. By promoting parasympathetic activation and relaxation, it is possible to prevent the deleterious effects associated with occupational stressors. **Conclusion:** The intervention with cardiovascular biofeedback proved to be superior to placebo in improving cardiac coherence, resulting in the recovery of the body's homeostasis. **Clinical Trials Register**: NCT04446689

Keywords (Source: DeCS)
Clinical Trial; Nursing, Team; Biofeedback, Psychology; Emotional Adjustment; Occupational Health .

Coherencia cardiaca y eficacia del biofeedback cardiovascular en personal de enfermería: ensayo clínico aleatorizado*

* Este artículo es derivado de la tesis de doctorado en Enfermería de título "Efeito do biofeedback cardiovascular sobre o coping da equipe de enfermagem: ensaio clínico randomizado" presentada a la Universidade Federal do Rio Grande do Sul, programa de posgrado en Enfermería. Disponible en: http://hdl.handle.net/10183/249381

Resumen

Introducción: a través de la respiración profunda guiada y consciente, el biofeedback cardiovascular, una herramienta tecnológica innovadora, permite mejorar la coherencia cardiaca y la activación del sistema nervioso parasimpático, fundamentales para recuperar y mantener la homeostasis y la salud psicoemocional. **Objetivo:** analizar el efecto del biofeedback cardiovascular sobre los parámetros de variabilidad de la frecuencia cardiaca en profesionales de enfermería. **Materiales y método:** ensayo clínico aleatorizado con dos grupos —biofeedback y placebo— realizado con 115 profesionales de enfermería que trabajaban en unidades de hospitalización clínica y quirúrgica de un hospital universitario, que presentaban un nivel de estrés global superior a 1, según la Escala de Síntomas de Estrés. Los grupos participaron en nueve reuniones a lo largo de tres semanas. El desenlace se evaluó mediante parámetros de rMSSD y coherencia cardiaca al final de cada reunión, medidos con el EmWave Pro Plus®, que utiliza la fotopletismografía para cuantificar los datos fisiológicos relacionados con los latidos del corazón. El análisis se realizó mediante ecuaciones de estimación generalizada, considerando $\alpha = 5\%$. Resultados: se evidenció una interacción significativa tiempo-grupo en los parámetros de coherencia cardiaca; el grupo de intervención presentó un aumento de los parámetros medios de coherencia cardiaca en todos los momentos de medición en comparación con el grupo de control ($p < 0,001$; $r > 0,98$). No hubo una interacción significativa entre el tiempo y el grupo en los parámetros rMSSD en ninguno de los tiempos de medición ($p = 0,432$). Como terapia mente-cuerpo, el biofeedback cardiovascular demostró ser útil y prometedor, ya que al promover la activación parasimpática y la relajación es posible prevenir los efectos deletéreos asociados a los estresores ocupacionales. **Conclusión:** la intervención con biofeedback cardiovascular tuvo un efecto mayor que el placebo en la mejora de la coherencia cardiaca, lo que se tradujo en la recuperación de la homeostasis del organismo.
Registro *Clinical Trials*: NCT04446689.

Palabras clave (Fuente: DeCS)
Ensayo clínico; personal de enfermería; *biofeedback* psicológico; ajuste emocional; salud de los trabajadores.

Coerência cardíaca e eficácia do biofeedback cardiovascular na equipe de enfermagem: ensaio clínico randomizado*

* Este artigo é derivado da tese de doutorado em enfermagem intitulada "Efeito do biofeedback cardiovascular sobre o coping da equipe de enfermagem: ensaio clínico randomizado", submetida ao Programa de Pós-Graduação em Enfermagem da Universidade Federal do Rio Grande do Sul, Brasil, disponível em: http://hdl.handle.net/10183/249381

Resumo

Introdução: a partir de uma respiração profunda guiada e consciente, o biofeedback cardiovascular, ferramenta tecnológica inovadora, possibilita melhorar a coerência cardíaca e a ativação do sistema nervoso parassimpático, fundamentais para a recuperação e manutenção da homeostase e da saúde psicoemocional. **Objetivo**: verificar o efeito do biofeedback cardiovascular sobre os parâmetros da variabilidade da frequência cardíaca dos profissionais da enfermagem. **Materiais e método**: ensaio clínico randomizado, com dois grupos — biofeedback e placebo —, realizado com 115 profissionais de enfermagem atuantes em unidades de internação clínica e cirúrgica de um hospital universitário, que apresentaram nível geral de estresse maior que 1, conforme a Escala de Sintomas de Estresse. Os grupos participaram de nove encontros por três semanas. O desfecho foi avaliado pelos parâmetros rMSSD e pela coerência cardíaca, ao final de cada encontro, aferidos através do EmWave Pro Plus®, que utiliza fotopletismografia para a quantificação de dados fisiológicos relacionados ao batimento cardíaco. A análise foi feita por equações de estimação generalizadas, considerando $\alpha = 5\ \%$. **Resultados**: evidenciou-se interação tempo-grupo significativa nos parâmetros da coerência cardíaca; o grupo intervenção teve aumento nas médias dos parâmetros da coerência cardíaca em todos os momentos de aferição quando comparado ao grupo controle ($p < 0{,}001$; $r > 0{,}98$). Não houve interação tempo-grupo significativa nos parâmetros da rMSSD em nenhum dos momentos de aferição ($p = 0{,}432$). Como terapia mente-corpo, o biofeedback cardiovascular mostrou-se útil e promissor, ao promover ativação parassimpática e relaxamento possibilita a prevenção de efeitos deletérios associados aos estressores ocupacionais. **Conclusão**: intervenção com biofeedback cardiovascular demonstrou efeito superior a placebo na melhora da coerência cardíaca, refletindo em recuperação da homeostase do organismo.
Registro *Clinical Trials*: NCT04446689.

Palavras-chave (Fonte DeCS)
Ensaio clínico; equipe de enfermagem; biorretroalimentação psicológica; ajustamento emocional; saúde do trabalhador.

Introduction

Nursing professionals are highly susceptible to stressful life events. Due to the nature of their profession, they experience suffering, uncertainty, and the loss of patients (1, 2), in addition to other sources of stress, such as interpersonal conflicts, excessive demands, the constant need for technical-scientific and technological training, feelings of devaluation, lack of professional autonomy and, often, unhealthy working conditions. Furthermore, they experience a complex, multifaceted work routine permeated by stressors, which exacerbates psychophysiological dysfunctions (2-5).

The autonomic nervous system (ANS) has a key role in the regulation of physiological processes and the homeostatic balance of the human body. Neglected stress is one of the main causes of ANS dysfunction and can trigger several psychological and physical pathologies, such as depression, post-traumatic stress, burnout, and somatization with cardiovascular, respiratory, and immunological repercussions, among others. As a result, it negatively affects the professionals' health and, consequently, the performance of their work activities (6-10).

Among the techniques used to assess and partially manage ANS, heart rate variability (HRV) has emerged as a promising, non-invasive measure of autonomic balance, based on photoplethysmography (7, 11, 12). HRV describes the oscillations in the interval between consecutive heartbeats (R-R intervals within the QRS complex), as well as oscillations between consecutive, instantaneous heart rates. Changes in HRV patterns provide a sensitive early indicator of health impairment. Since low HRV rates often indicate abnormal and insufficient ANS adaptation, this implies the presence of physiological dysfunction, which can be associated with psycho-emotional disorders such as stress (10, 12-14).

Cardiac coherence, one of the parameters of HRV, which is achieved when the heart rhythm is in sync and resonance with the respiratory rhythm, ensures an increase in the amplitude of heartbeat oscillations. Therefore, an increase in HRV rates indicates good or sufficient adaptation of the ANS to the environment or a given stressful situation (12, 15).

Cardiovascular biofeedback is an integrative and complementary mind-body practice that uses breathing to control autonomic function. It also allows individuals to learn how to modulate the body's response based on information from HRV. To this end, sensors are placed next to the individual's body to monitor bodily functions and, simultaneously, a computerized system translates this information into visual or sound signals that provide feedback to the individual (11, 12, 16, 17).

Cardiovascular biofeedback has been reported to be effective in treating various clinical conditions and preventing and relieving symptoms related to physiological and subjective stress. It also improves performance, especially in professionals whose work requires efficient stress management, such as athletes, police officers, and managers (12, 16, 18, 19). Studies on the use of biofeedback in nursing professionals and the benefits for this group are still scarce, thus it is urgent to explore non-pharmacological tools that can minimize the negative repercussions of stress and preserve these professionals' homeostatic balance (20-23).

Based on the above, the objective is to verify the effectiveness of cardiovascular biofeedback on the HRV parameters of nursing professionals working in a university hospital, when compared to a computerized activity without self-monitoring.

Materials and Methods

Study Design and Location

This is a double-blind, parallel randomized clinical trial comparing two groups, conducted from June 2020 to August 2021, with the Nursing Group of the *Hospital de Clínicas de Porto Alegre*, Brazil, an institution regarded as a reference center for health care and research in Rio Grande do Sul. The study was conducted in line with the guidelines of the Consolidated Standards of Reporting Trials (Consort).

Participants and Recruitment

The study population consisted of nursing professionals of both sexes, currently working as nurses, who had been hired for over 90 days, considering the institutional legislation regarding the validity of the probationary contract, working any shift scheduled at the institution, allocated to the surgical nursing, clinical nursing, or clinical inpatient nursing services, which have similar characteristics in terms of infrastructure, organization, lighting, and the type of patient receiving care, not involve with the hospitalization of patients with COVID-19 and with a general stress level greater than 1 (GSL > 1).

The GSL was determined based on the Stress Symptom Scale. The scale's internal consistency during validation was $\mu = 0.92$ for psychological symptoms and $\mu = 0.90$ for physical symptoms. Based on the arithmetic mean of the items on this scale, the GSL was calculated, where values greater than 1 indicate the presence of stress, ranging from 1.1 (lowest stress) to 2.95 (maximum stress [24]).

The professionals excluded from the sample were those on long-term sick leave (social security benefits and pregnancy or lactation leave) and vacation, or who returned less than 15 days before their leave, professionals using pacemakers or who have heart rhythm disorders (arrhythmia, tachycardia, and/or bradycardia).

The sample size calculation was estimated by the condition of interest —stress— and based on a randomized clinical trial that showed a difference in stress levels immediately after the intervention (Cohen's d = -0.33), as well as six weeks after implementing the intervention (Cohen's d = -0.68 [25]). Considering a one-tailed sample with a significance level of 5 %, power of 90 %, standardized effect size (Cohen's d) of at least 0.4 between evaluations, and loss estimates of 5 % (no follow-up of participants expected), a minimum sample of 57 professionals in the intervention group (IG) and 57 professionals in the control group (CG) was obtained, totaling 114 participants.

Participant Selection Logistics

The researchers randomly selected the participants, respecting the eligibility criteria, based on the work schedules of each nursing service, using the "Name Draw" app for Android®. The professionals selected were briefed on the study and received an informed consent form, as well as the research protocol, consisting of questionnaires and scales for measuring the variables of interest.

It is worth noting that the socio-occupational and health information questionnaire was designed by the researchers to collect data on the participants' socio-biographical, socio-occupational, health conditions, and self-reported previous illnesses.

Eligible professionals were randomized into IG and CG and then invited to participate in the randomized clinical trial. Block randomization was decided via randomization.com, which ensured that the number of participants was equally distributed in the groups. Furthermore, it was conducted by one of the researchers who was not involved in performing the activities with the participants to ensure that the sample was randomized.

Once the research subjects had provided their consent, the researcher or research assistant scheduled the first appointment (to). All procedures, regardless of the allocation group, were conducted during the participant's working hours and in a private location close to their work unit. Subjects were included in the study gradually, from June 2020 to August 2021, until the minimum sample of 57 professionals per group was reached.

Outcome

The outcome —improvement in HRV parameters— was evaluated by the root-mean-square differences of successive R-R intervals (rMSSD), understood as the root mean square difference of successive R-R intervals. The rMSSD is one of the parameters of the HRV time domain and is measured in milliseconds (ms). It was also evaluated by cardiac coherence — understood as the synchrony frequency between cardiac and respiratory rhythms — which is one of the parameters of the frequency domain of HRV and is measured in milliseconds per Hertz (ms/Hz). Both variables were measured using the HRV Assessment module of the EmWave Pro Plus® software, developed and manufactured in the United States by Quantum Intech, Inc. Boulder Creek, and designed by the HeartMath Institute. This software uses a photoplethysmography sensor, which is a reliable, valid, and accurate method for capturing and quantifying physiological data related to the heartbeat in real time. It is the standard recommended for analyzing HRV in the time and frequency domain (26).

The sensors were installed in the participants' earlobes and, regardless of whether they were in the IG or CG, the HRV parameters were monitored and recorded as follows: baseline measurement in the first appointment (t0) and measurement for five minutes in the eight following appointments (from t1 to t8), performed after the activity planned for the session according to the allocation group.

Intervention

The intervention consisted of training in the cardiovascular biofeedback technique, using the interface and interactive games available in the EmWave Pro Plus® software. During the interactive game, based on the physiological behavior measured, the software generates continuous and dynamic information allowing the participant to gradually improve their respiratory and cardiac rhythm by maintaining the rhythm and concentration with guided and standardized breathing (26).

Due to the peculiarities of the work routine of nursing professionals, the intervention was divided into nine appointments, which were held three times a week for three weeks. At t0, baseline HRV was measured, and instructions were provided on the dynamics of the next appointments.

In the following IG appointments (from t1 to t8), guided deep breathing training was provided, at a controlled and standardized rate, with the assistance of the York Biofeedback Breath Pacer software (standardized "breathing" at six breaths per minute, 50/50 inhalation ratio, with a pause after inhalation of 32 % and after exhalation of 20 %, prevalent in 95 % of the population), combined with biofeedback, through interactive games provided by the EmWave Pro Plus® software, lasting ten minutes per session. Participants were instructed on how to perform guided deep breathing, as well as on the biofeedback data collected through the sensor installed in the earlobe and viewed through the interface projected on the computer screen for breathing self-modulation.

The control consisted of performing a computerized activity without self-monitoring to keep the groups blinded. For this purpose, the Jigsaw Puzzles online application was used, which consists of puzzles at varying levels of difficulty, which was played on a tablet.

Every professional in the CG participated in the study for nine sessions. At t0, baseline HRV was measured and in the following appointments, computerized activities were conducted without self-monitoring, lasting ten minutes per session. EmWave Pro Plus® was also used, and the sensor was installed in the participant's earlobe, without them being able to see the interface projected onto the computer screen. The equipment was cleaned with a cloth soaked in 70 % isopropyl isopropyl alcohol before and immediately after the activity.

To access and use the HRV monitoring system, interactive games, and their respective evaluations, it was necessary to purchase photoplethysmography sensor devices via the HeartMath Institute website: EmWave Ear Sensor and EmWave USB Sensor Module, and licenses to download and access the full version of the EmWave Pro Plus® software, which was installed on laptop computers, in addition to completing a training course. The York Biofeedback Breath Pacer respiratory stimulation system is available to download and access free of charge on the York Biofeedback website.

Blinding and Data Collection Procedure

The participants were blinded to ensure that they were unaware of whether they were being included in the IG or CG. The data collection instruments were self-administered and handed to participants in a brown envelope. They were collected on a date agreed upon by the participant and the researcher, and the data were double-entered into Excel spreadsheets. The HRV data recorded by the software were compiled in Excel spreadsheets at the end of each session and checked against the digitally saved records.

Due to the restriction on the number of research assistants because of the pandemic, and the peculiarity of the activities in the groups, it was not possible to blind the researchers and assistants who conducted the activities with the IG and CG. All members of the research team were fully trained to maintain homogeneity in the approach, guidance, and implementation of the proposed intervention.

Blinding was considered when analyzing the data. Hence, before the statistical consultancy, the databases of both groups were unified and coded regarding the allocation of participants.

Statistical Analysis

The data were analyzed using the SPSS statistical package, version 20.0. The distribution of continuous variables was assessed for normality using the Shapiro-Wilk test. Variables with a normal distribution were compared using Student's t-test and, in the event of asymmetry, the

Mann-Whitney test was used. Pearson's Chi-squared or Fisher's exact tests were used to compare proportions.

To assess the intervention's effect, considering that the measurements have been performed three or more times, *Generalized Estimating Equations* [GEE] were employed, with multiple comparisons, and with Bonferroni's correction (*post hoc*). The interaction's size was verified based on the difference mean (IG-CG) and on the confidence interval (CI) between the groups. The effect size was calculated based on Cohen's d.

Ethical Aspects

The present study was conducted in line with the ethical principles for research with human beings. It is linked to a matrix project proposed by the Occupational Health Interdisciplinary Team of the Universidade Federal do Rio Grande do Sul (20), registered in the Clinical Trials database, entitled "Biofeedback ef[f]ects on stress, anxiety, and quality of professional life on [the] nursing staff of an (sic) university hospital", under registration number NCT04446689, and approved by the Research Ethics Committee of the *Hospital de Clínicas de Porto Alegre*, under ethics approval submission certificate number 23346619.0.0000.5327 and opinion number 3.796.246.

Results

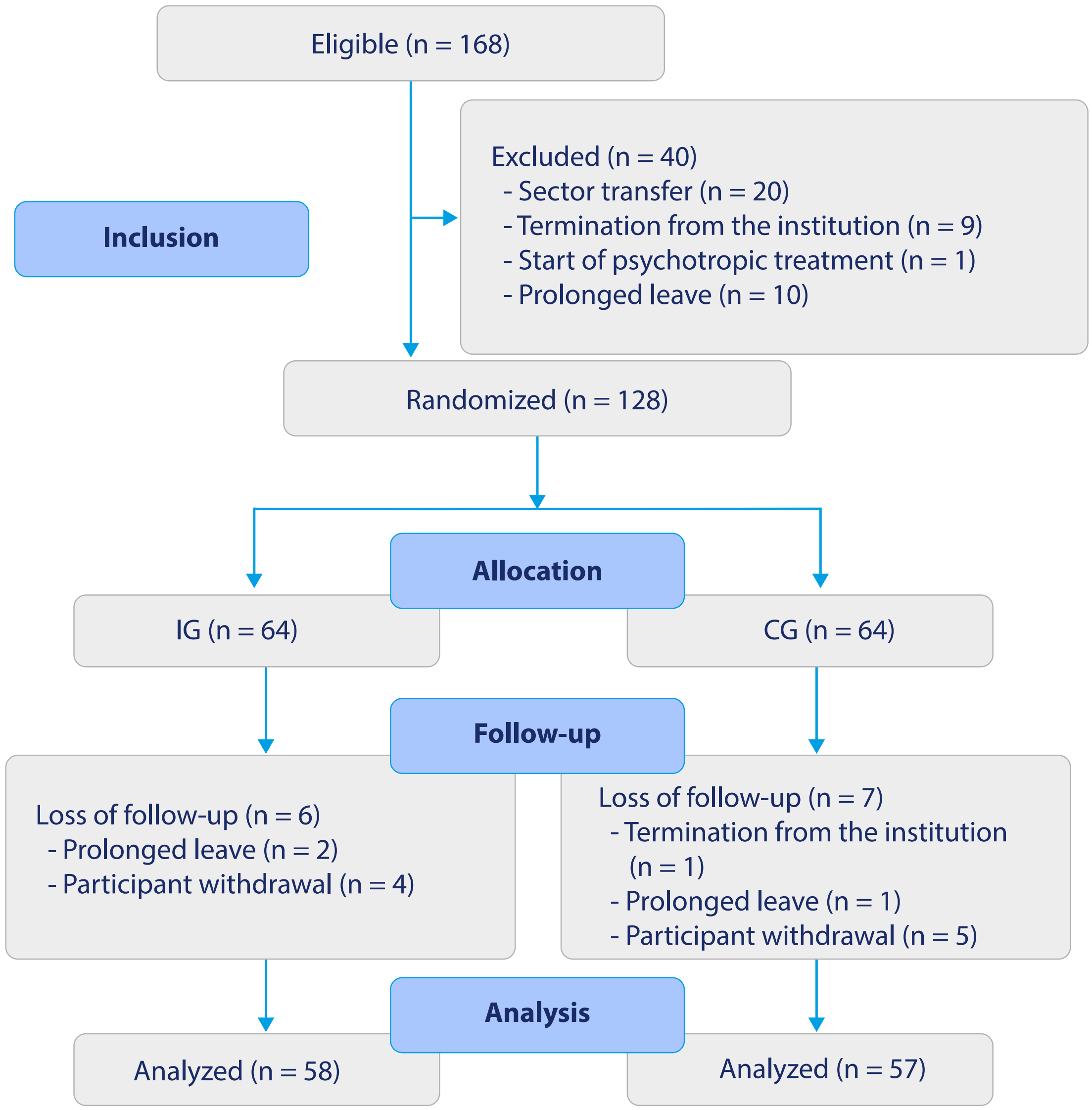
During the recruitment stage, 168 professionals showed stress symptoms. Reorganization due to the COVID-19 pandemic regulations there were relocations, leaves, and terminations of recruited professionals, which led to the exclusion of 40 professionals from the sample.

Of the 128 professionals included and randomized into the IG and CG, six participants in the IG and seven in the CG suffered follow-up losses. The analysis included a total of 115 nursing professionals as detailed in the flowchart of the participants in the study (Figure 1), developed in compliance with the Consort guidelines.

The participants' sociodemographic, occupational, and health characteristics are described in Table 1. There were no statistically significant differences between the groups ($p > 0.05$), indicating that the sample was homogeneous.

For detailing this study's results, the rMSSD and cardiac coherence parameters will be analyzed exclusively for the effect of the time versus group interaction, since comparisons between groups and between sessions (time) are not suitable for measuring the effect of the intervention.

Figure 1. Flowchart of the Participants in the Study, in Line with the Consort Guidelines. Porto Alegre, Rio Grande do Sul, 2021



Source: elaborated by the authors.

Table 1. Sociodemographic, Occupational, and Health Characteristics of IG and CG Participants. Porto Alegre, Rio Grande do Sul, 2021

Characteristics	IG	CG	p-value
	(n = 58)	(n = 57)	
Age (years)*	42.2 ± 7.5	44.1 ± 9.3	0.235
Female**	47(81.0)	52(91.2)	0.190
Professional category**			0.993
Nurse	23(39.7)	22(38.6)	
Nursing assistant	9(15.5)	9(15.8)	
Nursing technician	26(45.6)	26(44.8)	

Characteristics	IG	CG	p-value
	(n = 58)	(n = 57)	
Shift**			0.923
Morning	18(31.0)	21(36.8)	
Afternoon	22(37.9)	19(33.3)	
Night	13(22.4)	12(21.1)	
Intermediate	05(8.8)	05(8.8)	
Nursing experience (years)*	16.8 ± 6.7	18.3 ± 7.8	0.259
Single employment relationship**	50(86.2)	46(80.7)	0.587
Regularly used medication**			0.653
Antihypertensive(s)	6(10.3)	10(17.5)	
Psychotropic(s)	11(19.0)	11(19.3)	
Heartbeats per minute*	81 ± 1.5	79 ± 1.3	0.257
Practices physical activity**	29(50.0)	24(42.1)	0.508
Receives follow-up for psychological/ mental health**	12(20.7)	15(26.3)	0.623
Smoker**	6(10.3)	8(14.0)	0.749
24-hour sleep time*	6.6±1.5	6.8±1.4	0.299
Consumption of stimulating beverages (300ml or more per day)**	46(79.3)	41(71.9)	0.481

*mean ± standard deviation (t-test); ** absolute and relative frequency (%) (Chi-squared).
There was no significant difference at $p < 0.05$ between IG and CG.

Source: elaborated by the authors.

Table 2 displays the effect of the cardiovascular biofeedback intervention on rMSSD. The GEE results show that there was no significant time-group interaction for rMSSD ($p = 0.432$) at any of the measurement times. It should be noted that, although not statistically significant, the mean difference of the interaction was considerably higher for the IG at t3, with an increase of 14.07 points in rMSSD compared to the CG ($p = 0.323$). Furthermore, in the two following intervention sessions (t4 and t5), the IG presented a reduction of -8.22 and -11.21 points respectively in the rMSSD compared to the CG ($p = 0.568$ and $p = 0.241$).

Table 2. Description of the rMSSD mean in the IG and CG, and the effect of the interaction between time and group in each session (t). Porto Alegre, Rio Grande do Sul, Brazil, 2021

Session	rMSSD				
	IG*	CG*	Time-Group Interaction**		p-value
			Mdif	CIdif 95 %	
t0	49.8 ± 4.3	47.1 ± 4.0	2.76	-08.78 - 14.29	0.639
t1	65.7 ± 8.6	58.1 ± 6.5	7.60	-13.55 - 28.76	0.481
t2	61.8 ± 5.9	58.1 ± 6.9	3.67	-14.10 - 21.45	0.686
t3	82.0 ± 12.2	67.9 ± 7.3	14.07	-13.85 - 41.99	0.323
t4	70.5 ± 9.7	78.7 ± 10.6	-8.22	-36.40 - 19.96	0.568
t5	56.2 ± 5.0	67.4 ± 8.1	-11.21	-29.97 - 07.54	0.241
t6	66.4 ± 7.0	65.3 ± 7.9	1.05	-19.70 - 21.79	0.921
t7	64.6 ± 7.7	67.5 ± 9.8	-2.85	-27.33 - 21.62	0.819
t8	73.3 ± 10.9	72.4 ± 11.0	0.95	-29.45 - 31.33	0.952

*mean ± standard deviation (t-test); **GEE; M_{dif} (difference mean = IG-CG); CI_{dif} 95 % (confidence interval for the difference); *p-value* (statistical significance at p < 0.05).

Source: elaborated by the authors.

Table 3 shows the effect of the cardiovascular biofeedback intervention on cardiac coherence. The GEE results indicate that there was a significant time-group interaction for cardiac coherence (p < 0.002) at all measurement times. It is worth noting that the means for the difference (interaction size) showed a considerable increase after the first training session with cardiovascular biofeedback (t1), in which the IG showed an increase of 28.10 points in cardiac coherence when compared to the CG (p < 0.001), with a large effect size (Cohen's d = 14.86; r = 0.99). The greatest interaction effect occurred at t5 when the IG showed a 30.18-point increase in cardiac coherence rates compared to the CG (p < 0.001; Cohen's d = 17.71; r = 0.99). Excluding the baseline measurement (t0), the smallest interaction size occurred after the last cardiovascular biofeedback training session (t8), in which the IG showed a 25.62-point increase in cardiac coherence compared to the CG (p < 0.001); still, with a large effect size (Cohen's d = 13.79; r = 0.98).

Table 3. Description of the Mean Cardiac Coherence in the IG and CG and the Effect of the Interaction between Time and Group in each Session (t). Porto Alegre, Rio Grande do Sul, Brazil, 2021

Session	Cardiac coherence				
	IG*	CG*	Time-Group Interaction**		p-value
			Mdif	CIdif 95 %	
t0	43.8 ± 2.1	35.8 ± 1.5	8.04	02.89 - 13.18	0.002
t1	64.5 ± 2.3	36.4 ± 1.4	28.10	22.84 - 33.35	<0.001
t2	62.1 ± 2.4	34.2 ± 1.0	27.82	22.70 - 32.94	<0.001
t3	62.4 ± 2.6	33.7 ± 1.2	28.70	23.16 - 34.23	<0.001
t4	61.0 ± 2.4	32.4 ± 1.4	28.65	23.22 - 34.08	<0.001
t5	63.7 ± 2.1	33.6 ± 1.2	30.18	25.41 - 34.95	<0.001
t6	60.2 ± 2.3	34.3 ± 1.1	25.89	20.75 - 31.03	<0.001
t7	59.5 ± 2.4	32.7 ± 1.1	26.83	21.60 - 32.07	<0.001
t8	59.5 ± 2.4	33.9 ± 1.1	25.62	20.36 - 30.88	<0.001

*mean ± standard deviation (t-test); **GEE; M_{dif} (difference mean: IG-CG); CI_{dif} 95 % (confidence interval for the difference); *p-value* (statistical significance at $p < 0.05$).

Source: elaborated by the authors.

Discussion

The effectiveness of the intervention with cardiovascular biofeedback in improving the cardiac coherence parameters of nursing professionals working in hospital sectors was found in this study, which was evaluated using the EmWave Pro Plus® HRV Assessment module.

The time-group interaction showed that cardiac coherence rates presented a statistically significant increase in the IG when compared to the CG, with a large effect size at all measurement times, as well as a tendency towards stability during the follow-up period.

This result corroborates those of previous studies conducted with different populations (12, 27) and replicates the foundational relationship between cardiac coherence and emotions (8) since an increase in cardiac coherence biomarkers is associated with the use of tools for respiratory modulation and, consequently, for the physiological relaxation response.

In a study conducted in France, healthy individuals were exposed to a period of stress and then either practiced biofeedback techniques (n = 15) or watched a neutral video (n = 14). The results showed that biofeedback is a proactive and relevant tool for coping with stress. Compared to the group that watched the video, participants who practiced biofeedback achieved higher cardiac coherence scores and medium effect size ($F_{2,33} = 28.34$, $p < 0.001$, $\eta 2 = 0.63$). Post-intervention self-reported measurements showed that biofeedback contributed to reducing self-perceived psychological stress and increasing perceived levels of performance. In addition, participants estimated that 11 (± 5) minutes of biofeedback intervention was ideal for coping with an upcoming stressful event, promoting relaxation and better coping, among other positive effects for ANS balance (27).

The data presented in the paragraph above, although related to a study conducted with the French population (27), are similar to those found in the present study, which was conducted with nursing professionals who presented stress symptoms and in which the intervention with cardiovascular biofeedback showed a large effect size at all measurement times when compared to the placebo activity ($p < 0.001$; Cohen's d >13.79; $r > 0.98$).

The psychophysiological state of cardiac coherence, achieved when the heart rate accelerates and decelerates in harmony with the respiratory rate, contributes to positive changes in HRV and blood pressure, activating the body's regulatory and cyclical functions, such as the endocrine and neuroimmunological systems. Positive physiological changes, seen when individuals reach this state of synchrony and maintain it through breathing self-control, promote a lasting condition of ANS balance and emotional stability (12, 27).

In this study, the effectiveness of the intervention with cardiovascular biofeedback on the rMSSD parameters of the participating professionals could not be supported by the assessments using the EmWave Pro Plus® HRV Assessment module. Although at some points considerable mean differences were found in the interaction, these were not statistically significant in the time-group interaction. In fact, the participants' rMSSD behavior in both groups oscillated.

An equivalent result was reported in a previous study (27) conducted with healthy French individuals, in which rMSSD scores showed no statistically significant effect between the IG and CG ($\chi 2 = 1.21$, $p = 0.27$). In a meta-analysis conducted to analyze studies that justified selecting HRV as a psychological stress indicator, the authors found that the most frequently reported factor associated with variation in HRV variables was low parasympathetic activity (7).

However, it is worth understanding that although rMSSD quantifies ANS parasympathetic activity, in which passive relaxation responses and homeostasis recovery prevail, the data analyzed in the present study (rMSSD) provides the quantification of short-term variations in parasympathetic activation. Considering that, among other functions, the parasympathetic system reduces heart rate, it is clear that the oscillations in parasympathetic short-term variations do not reflect something negative, but possibly their action in opposition to sympathetic activity (8). Among the participants in this randomized clinical trial, this activation occurred in the bodies of individuals who self-reported stress and were learning to modulate their breathing to regain their psychophysiological balance.

Therefore, in line with studies conducted with different populations (7, 27), cardiovascular biofeedback can be considered a promising

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tool, in light of the physiological and psychological effects found in improving cardiac coherence, as well as in activating the parasympathetic system. In this study, these effects were achieved even without intensive training and with a standardized protocol for guided deep breathing.

Furthermore, as a mind-body therapy, cardiovascular biofeedback has proven to be a promising and useful tool in specific situations since, by promoting parasympathetic activation and relaxation, it can enable the prevention of a range of deleterious effects associated with occupational stressors (14, 16). In just ten minutes of cardiovascular biofeedback training, the nursing professionals participating in the IG learned how to modulate consciously and partially their body's responses, recovering homeostasis, as well as enabling self-knowledge and self-awareness of their feelings and emotions, according to physiological or pathological behaviors, minimizing the negative effects of occupational stressors.

It is worth considering that the study was conducted during the nurses' professional practice and, although the participants were not providing direct care to COVID-19 patients, they were experiencing the impacts and uncertainties stemming from the pandemic in their daily family, social, and organizational lives.

In this sense, the following limitations were identified: The inability to individualize the controlled frequency and/or resonant frequency for guided deep breathing training, due to the standardization of the activities performed to minimize bias in the research, in line scientifically recommended methodological principles; in addition, the logistics of the sessions, which, due to the work routine of the nursing team, were not conducted consecutively.

Conclusion

The intervention with cardiovascular biofeedback proved to have a greater effect than the placebo in improving the nursing professionals' cardiac coherence rates, whose physiological data were assessed using the EmWave Pro Plus® HRV Assessment module, which is reflected in the recovery of the body's homeostasis. There was no statistical evidence of an improvement in the rMSSD parameters, which quantify short-term variations in the parasympathetic activation of the ANS, in the participating nursing professionals.

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