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Heart rate variability in people with borderline type personality

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Abstract

Background: Reduced HRV is associated with a variety of conditions such as diabetic neuropathy, sepsis, myocardial infarction, but lately it has gained increased interest in psychiatry due to the connection between autonomic dysfunction and psychiatric pathologies. Borderline personality disorder (BPD) with an increased rate of cardiovascular mortality, and characterized by emotional instability, is ideal for studying heart rate variability.
Material and methods: 203 subjects were initially evaluated with Personality Inventory for DSM-5, PID-5, (DSM-5 – Diagnostic and Statistical Manual of Mental Disorders, 5th edition), and 2 groups have been selected: control group that included 69 subjects and borderline personality disorder (BPD) group that included 34 subjects. Heart rate variability (HRV) was analyzed from an electrocardiography signal, recorded in 3 conditions: resting, pain stimulation, period following the pain stimulation.
Results: In post-pain period, in subjects with BPD, the HRV parameters indicate an increase of sympathetic influences on heart rate and a reduction of vagal modulatory effects. The values in these subjects did not return to the initial values in the post-pain period as they did in the control group, but, on the contrary, the accentuation in the dynamics of the sympathetic influence was registered, even compared to the pain period.
Conclusions: Subjects with BPD presented an increased vagal modulation at rest, which was reduced during pain stimulation and did not return rapidly to the initial value after removing the painful stimulus, which can be proof of the inertia of autonomic influences in these subjects.
Key words: borderline personality disorder, heart rate variability.

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Introduction

Heart rate variability (HRV) is the time variation of the intervals between each heartbeat, recorded as RR intervals of the ECG signal. It is a complex physiological phenomenon that results from the change of heart rate by respiratory, circulatory, autonomic, endocrine and mechanical factors. Reduced HRV is associated with a variety of conditions such as diabetic neuropathy, sepsis, myocardial infarction, but lately it has gained increased interest in psychiatry due to the connection between autonomic dysfunction and psychiatric pathologies [1]. Changes in HRV have been reported in many mental disorders [1, 2] as well as correlations of HRV with psychological dimensions such as social cognition [2, 3], interpersonal relations [4, 5] and emotional regulation [6, 7] have been described. The increased incidence of cardiovascular disease associated with psychiatric pathologies has also led to increased attention to the autonomic nervous system. Borderline personality disorder (BPD) with an increased rate of cardiovascular mortality, and characterized by emotional instability, is ideal for studying heart rate variability. Changes in the heart rate occur due to a constant need of the heart to adapt to changing circumstances and it is believed that the loss of balance between the sympathetic and parasympathetic nervous system causes alteration of the HRV structure [8]. In this context, HRV is a measure of autonomic nervous system balance, and therefore may provide a quantification of the physiological changes associated with mental illness.

In the last two decades since the first studies appeared and until now, multiple connections between resting heart rate variability and psychological functions, including psychopathological expression, have been described. In general, these early studies, and many of those that appeared afterwards, showed that HRV correlates with various adaptive psychological effects among children, adolescents, and adults, including the empathic response to other sufferings [9, 10], social competence [5], ability to hold attention for a long time [11], cognitive performance [12], adjustments behavior during social challenges and positive interactions with partners [13]. Low HRV at rest, or a large reduction associated with various challenges (particularly emotions) are associated with symptoms of both introverted and extroverted psychopathology [6, 14-16], with a broad spectrum of psychopathological syndromes, including anxiety [12,

17], phobias [14], attention deficit [18], emotional insensitivity [6, 8, 18], behavior disorder [14, 15], depression [17], non-suicidal self-injury [17, 19], panic attacks [5, 7, 17]), hostility [12, 17, 19], psychopathy [12], schizophrenia and others. In addition, internalizing or externalizing comorbid symptoms predict an additional reduction in cardiac variability during emotional challenges than internalizing or externalizing symptoms of a self-esteem [17]. This impressive long list suggests that HRV at rest and low reactivity to emotional challenges mark one or more essential self-regulatory functions that are disturbed by various forms of psychopathologies. Understanding the neural bases of HRV, and determining the neural bases that give rise to plasticity phenomena, can therefore have important treatment implications, and is a key moment in the path to modifying circuits to reduce the adverse effects on mental health in vulnerable individuals.

BPD is characterized by personality traits in the field of negative affectivity, emotional lability, anxiety, separation insecurity or depression and behavioral characteristics such as disinhibition (including impulsivity and risk-taking) or antagonism (hostility) [20].

This represents a pervasive pattern characterized by instability in interpersonal relationships, self-image and affectivity, as well as by increased impulsivity, which begins at the young adult age, manifests through identity disorders, recurrent suicidal behavior, irritability or anxiety, sustained efforts to avoid a real or imaginary abandonment, chronic feeling of inner emptiness etc. The median prevalence in the population of BPD was estimated at 1.6%, but may reach 5.9%. Taking into account the increased prevalence of BPD of 6% in primary health care and up to 20% in specialized psychiatry centers [21] and the considerable deficiencies caused to patients, the study of heart rate variability could offer to physicians, especially those at primary level, an alternative to pharmacological treatment, by correcting the psychophysiological mechanisms that lead to the appearance of systemic dysfunctions.

Genetic researches on BPD have mainly focused on genes involved in serotoninergic and dopaminergic systems. Tryptophan hydroxylase is an enzyme involved in the 5-HT synthesis of the tryptophan amino acid. Most studies have shown that two isoforms of tryptophan hydroxylase (TPH-1 and TPH-2) are associated with BPD [22]. Serotonin transporter genes (5-HTT), especially 5-HTTLPR (serotonin-transporter-linked polymorphic region}, are associated with BPD, depressive, anxious and obsessive-compulsive traits, but not with suicidal or self-destructive behaviors. On the other hand, monoamine oxidase A (MAO-A), an enzyme that degrades monoamines, especially serotonin, is involved after its recovery from the synaptic cleft. It has been shown that patients with BPD have a variable number of MAO-A gene repeats different from healthy volunteers [22, 23]. The brain-derived neurotrophic factor (BDNF) involved in neurogenesis, synaptogenesis and regulation of serotonin metabolism, the BDNF Val66Val polymorphism could also play a role in the pathogenesis of BPD [24].

The main features of each personality disorder (PD) are emotional disorders that may manifest themselves in different ways, but nonetheless, they are rooted in neural organization. For example, emotional instability is a basic pattern observed in BPD. Other features of this disorder are the tendency toward suicide, outbursts of intense anger, stormy relationships and identity disorders [19]. All these patterns are related to increased attention or sensitivity to social-emotional indices in interpersonal scenarios, the tendency towards self-referential emotional processing and the mechanisms of unregulated emotional processing. Patients with BPD have great difficulty in moving from the psychic equivalence mode to the pretending mode and often retain their perception as an absolute fact [25].

Studies involving mental health and investigating differences in heart rate variability use numerous time, frequency, or non-linear methods that quantify HRV [15, 26-31].

However, there are no widely recognized standards for measuring and quantifying heart rate variability and the clinical interpretation of many features of variability remains contradictory or unknown. Studies involving the analysis of heart rate variability in mental pathologies have minimal standardization [27, 32-35] especially regarding the analysis of time intervals and the methods of recording ECG, making comparing the results of variability over different time intervals additionally difficult. The variations in the duration of the recordings, the degree of activity of the participants and the methods of data collection may be different. For example, data is usually collected when the participant is at rest; however, the participant's posture, time of day, recent consumption of food or drink and many other factors may contribute to heart rate variability. Stimuli in the form of pictures or exercises can be exposed during recordings, making comparison between studies difficult.

The purpose of the study is to determine the autonomic changes in people with borderline personality disorder by studying the variability of the heart rate both at rest and in the pain test.

Material and methods

The current study was designed to determine autonomic changes in people with borderline personality disorder by studying heart rate variability under the influence of painful stimuli.

203 subjects were initially evaluated, between March 2017 – February 2020, in *Nicolae Testemitsanu* State University of Medicine and Pharmacy at the Department of Human Physiology and Biophysics. All subjects had signed an informed agreement. The exclusion criteria were: acute or chronic cardiac diseases; medications that could influence heart rhythm variability. The psychometric evaluation, which preceded the recording of cardiac parameters, was performed using the Personality Inventory for DSM-5, PID-5 (DSM-5 – Diagnostic and Statistical Manual of Mental Disorders, 5th edition) [36], which is a tool for self-assessment of personality traits, developed by the Ameri-

can Psychiatric Association (AAP) in 2012. PID-5 has been translated into Romanian and validated by a working group consisting of the staff of *Nicolae Testemitsanu* State University of Medicine and Pharmacy and the Department of Headache and Vegetative Disorders within the Institute of Neurology and Neurosurgery, in compliance with the rules of translation, adaptation and validation of the International Test Commission and with the consent of the authors. PID-5 is a questionnaire, containing 220 personality self-report items, used to measure maladaptive personality traits, which are characterized in DSM-5. The answers are selected from a four-point scale, from 0 ("very false or often false") to 3 ("very true or often true"). Thus, PID-5 offers scores evaluated on a scale of 4 points, for the 25 facets. Each facet includes from 4 to 14 elements. These facets correspond to the maladaptive personality traits described in section III of the DSM-5 and are included in the five areas of higher order, also described in section III: negative affect, separation, antipathy, disinhibition and psychosis. The score greater than 2 in a certain number of facets is a quantitative index of one of the 6 types of PD: Antisocial, Borderline, Schizotypal, Avoidant, Obsessive-Compulsive or Narcissistic [20, 37, 38].

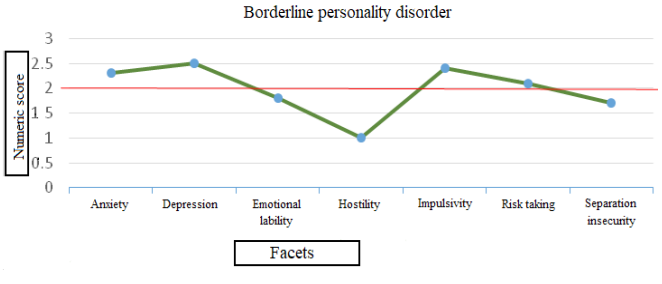

Fig. 1. Subject with Borderline personality disorder, with numerical scores greater than 2 in 4 facets.

Note: for the borderline personality disorder the distribution of the numerical scores of 7 facets is studied. For a positive result, it is necessary that 4 of the 7 facets to have scores greater than 2 on the axis of the ordinates.

Finally, based on the obtained results in the PID-5, the examined subjects were distributed in 2 groups, according to the number of the numeric scores greater than 2 in 4 out of 7 personality traits characteristic for the borderline personality disorder: Anxiety, Depression, Emotional Lability, Hostility, Impulsivity, Risk taking, Separation insecurity:

– First group – PID traits with all numerical score in the range 0-1.99, healthy people (control group);

– Second group – PID: 4 features out of 7 with numerical score more than 2.0, of which at least one to be an obligatory trait (marked in bold) (BPD group).

Subjects with numerical score greater than 2.0 in 1-3 facets of BPD were not included in the study. The BPD profile of a person who was included in the study shows that 4 of the 7 facets have a numeric score greater than 2 (fig. 1). The age of the people included in the study was between 18 and 60 years. The groups were homogeneously distributed according to sex, namely 53 women (mean age 41 years) and 49 men (mean age 39 years). Control group included 69 subjects (N = 69) with a mean age of 40 years (35 women and 33 men) and BPD group included 34 subjects (N = 34) with a mean age of 36 years (18 women and 16 men) (fig. 2, 3).

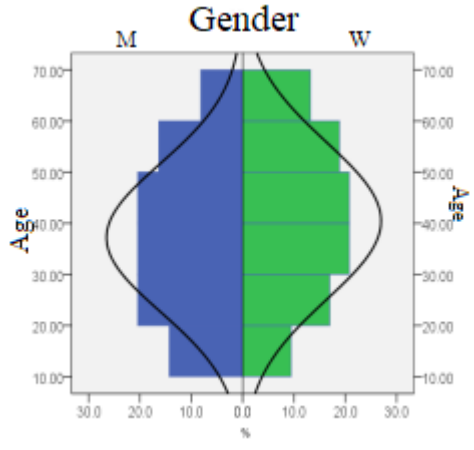

Fig. 2. Distribution of participants according to gender and age.

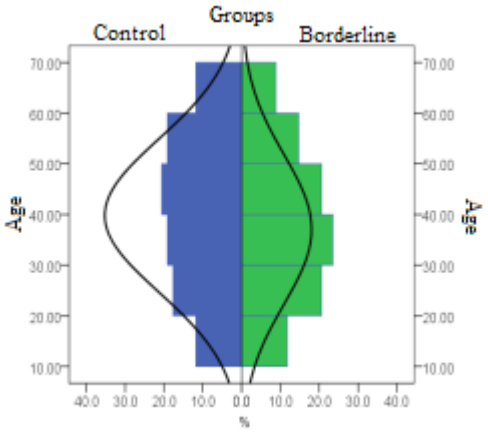

Fig. 3. Distribution of Control subjects and Borderline subjects according to age.

All studies were performed in the morning (08:00-10:00 AM) without the person's consuming any food that morning, in lying position. The experimental protocol included the recording of electrocardiogram in the standard II lead during 3 periods:

1. Breathing at rest (resting period) – in physical, mental and emotional resting conditions, 5 min;

2. Pain test (pain stimulation) – painful stimulus, the cuff of the sphygmomanometer at a constant pressure of 200 mm Hg was applied at the level of the left arm of the subject, for 5 min;

3. Post-pain period – the pressure was removed and recording continued for another 5 min.

The experimental protocol included the recording of ECG in subjects in lying position, in a quiet room, with moderate light, at comfort temperature. During the recording, the subjects were asked to breathe quietly, not to speak and to avoid additional movements.

The ECG signal was recorded using the system Biopac MP-100. The processing of the data was performed with the software "Kubios HRV Standard" (version 3.2.0, 2019), manually removing the artifacts.

The spectral analysis Fourier of the RR interval (NN) variation included the total spectral power TSP (ms^2) and calculation of the spectral components: very low frequency (VLF) – less than 0.04 Hz (ms^2), low frequency (LF) – between 0.04 and 0.15 Hz (ms^2) and high frequency (HF) – more than 0.15 Hz (ms^2). The normalized components LFnu and HFnu were calculated by division of power of components HF (ms^2) and LF (ms^2) by the total spectral power without VLF (ms^2) [32]. LF is often considered as an index of sympathetic modulation, and the HF component is used to evaluate the vagal activity. Following time domain parameters of the HRV were determined:

RMSSD – Root Mean Square of the Successive Differences in neighboring NN intervals (ms);

SDNN – the Standard Deviation of NN intervals during studied period (ms);

NN50 – the number of pairs of successive NNs that differ by more than 50 ms;

pNN50 – pNN50, the proportion of NN50 divided by total number of NNs.

The statistical analysis was performed using IBM SPSS Statistics 23.0 software, t-Student test was used to compare the HRV values inside the groups and between the groups.

Results and discussions

The data about HRV in people with BPD compared to healthy people presented in a review that analyzed HRV in mood disorders, including BPD, in the papers published between 1980 and May 2017 and found in PubMed, PsycINFO, Google Scholar and the Cochrane Library [33] are highly controversial. Our study confirms the heterogeneity of the results obtained by the HRV analysis between the people with BPD and healthy at rest as well as during pain test and after it.

HRV parameters of the time domain method (NN50, pNN50, SDNN and RMSSD) as well as LFnu and HFnu did not show significant differences between the groups included in the study at rest. In the pain test, the differences have been found between the parameters in the frequency domain of the HRV, namely LFnu is 13.9% lower in the BPD group (50.30 ± 3.60) compared to the control group (58.42 ± 2.37), p <0.05; (fig. 4) and respectively HFnu is 19.4% higher in the BPD group (49.45 ± 3.58) compared to the control group (41.39 ± 2.36), p <0.05; (fig. 5).

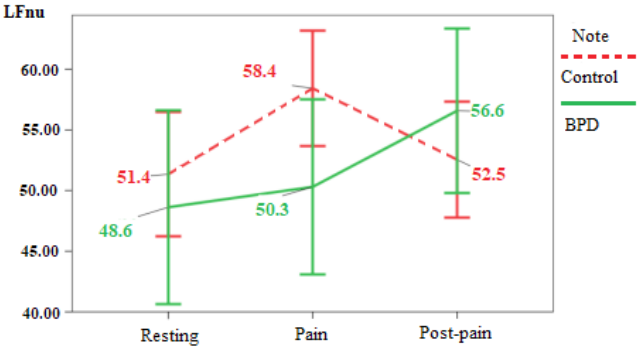

Fig. 4. LFnu values in subjects in control group and BPD group.

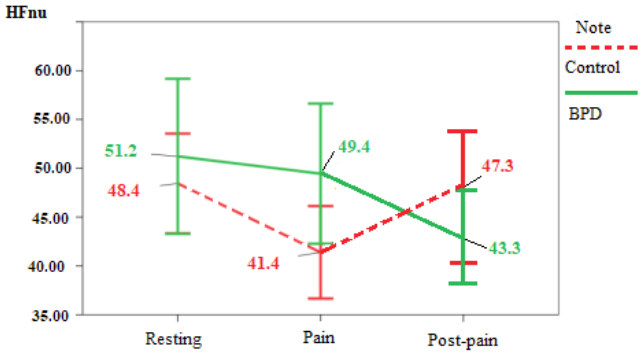

Fig. 5. HFnu values in subjects in control group and BPD group.

The veracity of the comparative differences between the functional tests was more evident within the study groups. In the group with BPD the pain caused a decrease of RMSSD by 10% (44.23 ±10.2 compared to 49.26 ± 10.95 at rest), p <0.05; other changes were not detected (tab. 1).

Table 1

HRV parameters in control and BPD groups

Test / HRV	Study groups					
	Control group (N=69)			BPD group (N=36)		
	Resting	Pain	Post-pain	Resting	Pain	Post-pain
RR (NN) (*ms*)	875.67 ± 18.4	868.84 ± 17.65	878.90 ± 16.80$^{\Delta}$	825.61 ± 24.53	828.05 ± 25.24	830.62 ± 22.71
SDNN (*ms*)	50.23 ± 5.17	49.13 ± 4.14	53.29 ± 4.34$^{\Delta}$	54.51 ± 7.02	50.29 ± 6.45	59.16 ± 6.42 $^{\Delta\Delta\Delta}$
RMSSD (*ms*)	46.18 ± 5.99	42.84 ± 5.06	45.34 ± 5.39	49.26 ± 10.95	44.23 ± 10.2*	50.88 ± 10.1 $^{\Delta\Delta}$
pNN50	16.46 ± 2.76	16.42 ± 2.65	17.84 ± 2.71	16.92 ± 3.36	16.73 ± 3.45	19.41 ± 3.67 $^{\varnothing\ \Delta}$
LF/HF	1.64 ± 0.24	2.10 ± 0.25	1.65 ± 0.27	1.56 ± 0.28	1.63 ± 0.33	2.06 ± 0.35
LFnu	51.35 ± 2.56	58.42 ± 2.37**	52.54 ± 2.38$^{\Delta}$	48.62 ± 3.99	50.30 ± 3.60	56.58 ± 3.38$^{\varnothing\varnothing\Delta}$
HFn	48.44 ± 2.55	41.39 ± 2.36**	47.36 ± 2.38$^{\Delta\Delta}$	51.22 ± 3.97	49.45 ± 3.58	43.28 ± 3.37$^{\varnothing\varnothing\ \Delta}$

Statistical differences between values within study groups. Resting /Pain: *– p<0.05; **–p<0.01; *** p<0.001. Resting/Post-pain: $^{\varnothing}$ – p<0.05; $^{\varnothing\varnothing}$ –p<0.0 $^{\varnothing\varnothing\varnothing}$ p<0.001. Pain/Post-pain: $^{\Delta}$ – p<0.05; $^{\Delta\Delta\Delta}$ –p<0.0$^{\Delta\Delta\Delta}$ p<0.001.

In contrast, after the removal of the painful stimulus, statistically significant differences in several time domain parameters of the HRV are observed in post-pain period versus pain stimulation and resting in the BPD group. pNN50 was 14.7% higher in the post-pain period (19.41 ± 3.67) than at rest (16.92 ± 3.37), p <0.05; SDNN – was 18% higher post-pain (59.16 ± 6.42) compared to (50.29 ± 6.45) during pain, p <0.001; and RMSSD was with 15% higher during post-pain period (50.88 ± 10.1) than during pain stimulation (44.23 ± 10.2), p <0.01 (tab. 1).

The components of the spectral analysis Fourier, LFnu and HFn, were different in post-pain period in comparison with resting and pain test. We reported an increase of LFnu by 16.3% in BPD group in post-pain (56.58 ± 3.39) compared to rest (48.62 ± 3.99), p <0.01, and by 12% in post-pain (56.58 ± 3.38) compared to pain period (50.30 ± 3.60), p <0.05, which indicates an increase in activity pf the sympathetic autonomic nervous system. HFnu was 15.5% lower in post-pain (43.28 ± 3.37) than at rest (51.22 ± 3.97), p <0.01; and by 13% lower in post-pain (43.28 ± 3.37) than in pain period (49.45 ± 3.58), p <0.05.

The time domain parameters: RR (NN), SDNN, RMSSD, pNN50 within the control group did not show significant changes in both pain stimulation and post-pain period compared to rest.

During pain stimulation in the control group, we could see statistically significant differences between the LFnu and HFnu values compared to rest: LFnu was 14% higher during pain (58.42± 2.37) than in resting period (51.35 ± 2.56), p <0.01; HFnu was 15% lower during pain (41.39 ± 2.36) than in resting period (48.44 ± 2.55), p <0.01 (tab. 1).

In the control group the pain stimulation produced statistical changes in LFnu and HFn, and in the BPD group the pain stimulation did not produce statistically valid changes, which speaks about a delayed activation of the autonomic nervous system in subjects with BPD.

During post-pain period in the control group, we observed statistically significant changes in the HRV; the average duration of the RR interval increases by 1% in post-pain period (878.90 ± 16.80) compared to pain stimulation (868.84 ± 17.65), p <0.05; SDNN was increased by 8% in post-pain period (53.29 ± 4.34) in comparison with pain stimulation (49.13 ± 4.14), p <0.05.

HFnu was by 14% higher during post-pain period (47.36 ± 2.38) compared to pain stimulation (41.39 ± 2.36), p <0.01; LFnu was decreased by 10% in post-pain period (52.54 ± 2.38) compared to pain stimulation (58.42 ± 2.37), p <0.05.

In subjects with BPD, higher HFnu values are observed at rest, marking an accentuated vagal modulation of the heart rhythm, and a lower sympathetic influence on the heart rhythm.

During the pain stimulation, a decrease of the vagal activity and an increase of the sympathetic activity on the heart rate were observed in both groups.

In post-pain period, LFnu and HFnu values in subjects with BPD were reversed compared to resting period, which indicates an increase of sympathetic influences on heart rate and a reduction of vagal modulatory effects. The LFnu and HFnu values in these subjects did not return to the initial values in the post-pain period as they did in the control group, but, on the contrary, the accentuation in the dynamics of the sympathetic influence was registered, even compared to the pain period.

Conclusions

1. The results regarding HRV in subjects with BPD, obtained in this study, are in concordance with the results of the studies in the research papers regarding the increased vagal modulation in subjects with BPD at rest, which is reduced during pain stimulation and does not return rapidly to the initial value after removing the painful stimulus, which can be the proof of the inertia of autonomic influences in these subjects.

2. Selecting the subjects for the study with the help of PID-5, translated and adapted for Romanian speakers in the Republic of Moldova, showed that PID-5 is a valid and useful tool for studying HRV in people with personality disorders.

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IM and VV conceptualized the project and designed the research; TB analyzed and described the data. SL and AG drafted the first manuscript. All authors revised and approved the final version of the manuscript.

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Conflict of Interests
No competing interests were disclosed.