THE NEW ARMENIAN MEDICAL JOURNAL
Vol.13 (2019), No 2, p.34-42

EFFECTS OF METEOROLOGICAL FACTORS ON HIGHER MENTAL FUNCTIONS AND AUTONOMIC NERVOUS SYSTEM IN SOUTHERN POPULATION

Evstafeva E.V.[1]*, Tymchenko S.L.[1], Zalata O.A.[1], Bogdanova A.M.[2]

V.I. Vernadsky Crimean Federal University, Medical Academy Named after S.I. Georgievsky;
Simferopol, Russian Federation
[1] Department of Normal Physiology
[2] Central Scientific Research Laboratory

Received 03.11.2018; accepted for printing 22.02.2019

Abstract

Numerous researchers have suggested that climate change affects both the onset and severity of cardiovascular and mental disorders at a population level, but its impact on higher mental functions (HMF) and autonomic nervous system (ANS) remains relatively unexplored. In order to evaluate the HMF and the autonomic regulation of the cardiac activity we examined forty-five individuals (18 males u 27 females; 18.7±0.6 year old) in September 2017 and February 2018.

Assessment of ANS was performed by heart rate variability (HRV) measurement, where five-minute HRV recordings by three-lead electrocardiography (Cardio, Ukraine) were obtained at rest in supine position and during cardiovascular reflex tests (active tilt test and deep breathing test) followed by analyzes of standard time and frequency domain HRV parameters. HMF were assessed by 4 standard tests: Schulte tables and Anisimov-Bourdon test to assess the characteristics of voluntary attention; "Wellbeing-Activity-Mood" questionnaire and State-Trait Anxiety Inventory for evaluation of psycho-emotional status.

Correlation analyses among autumn and winter registrations revealed significant associations between parameters of voluntary attention with wind velocity in September and with most of the meteorological factors in February. Most of the associations with meteorological factors (temperature and pressure) and anxiety were revealed during observation that coincided with the heat wave event in September 2017.

Identified associations between RRNN, RMSSD, pNN50, LF, VLF and humidity were suggestive for increased sympathetic activity during both cardiovascular reflex tests and these effects were similar in September and February. Negative correlation between the temperature and RRNN also indicates an increase in sympathetic activity as temperature increases during the deep breathing test.

These results suggest a moderate prevalence of the sympathetic regulation of the cardiac activity with low emotional stability during heat wave exposure that could be considered as a potential risk factor of cardiovascular morbidity brought about by climate changes.

Keywords: *climate change, meteorological factors, heart rate variability, higher mental functions, adaptation.*

Introduction

The growing evidence indicates that there is a need to improve assessment of the climate change on health and a new discipline – climate physiology where existing scientific knowledge overlaps with its practical applications might provide better insights. Using a wide range of approaches within the natural and medical sciences climate scientists carry out research to understand the fundamentals of health and environment effects of climate change to mitigate its negative impacts and to improve human adaptive capacity [*Kobysheva N, Klyueva M, 2016*]. Numerous data provided by the most relevant international and governmental research institutions suggest that climate change is creating truly unprecedented global health issues, including not only deterioration of health and consequences for mental health and human well-being

---

Address for Correspondence:
Elena V. Evstafeva, Prof., Dr. Sc.
V.I. Vernadsky Crimean Federal University, Medical Academy Named after S.I. Georgievsky,
5/7 Lenin blvd., Simferopol 295006, Russian Federation
Tel.: (+3652) 55 48 43
E-mail: e.evstafeva@mail.ru

[*Field C et al., 2014a; Trombley J et al., 2017*], but also a significant increase in the mortality rate [*Orru H et al., 2017*]. 5.5 million years of disability and approximately 150,000 annual deaths attributed to climate change stress in WHO's last assessment in 2014 [*Hales S et al., 2014*]. Now climate change is recognized by the world's international agencies as a serious health hazard with numerous publications addressing its impact on morbidity rate [*Field C et al., 2014a*], exacerbation of different diseases and acute events [*Kim K et al., 2014*; *Watts N et al., 2017*; *Vicedo-Cabrera A et al., 2018*]. Sensitivity to weather (meteorosensitivity) can be evaluated in both children and adults [*Grigoryev K, Povazhnaya E, 2018*].

The impacts of climate change include warming temperatures leading to hotter days and more frequent and longer heat waves that did not typically occur in relatively cold regions of the Russian Federation before. The current warming trend is of particular significance in southern regions because of exacerbate health effects resulting from the extreme temperature events [*Shartova N et al., 2018*] that makes local populations vulnerable to climate change despite their adaptation to the climate zone. Numerous climatic anomalies like record temperatures, snowfalls in spring and summer, flooding, storms were observed throughout the Russian Federation in 2017 [*Bardin M et al., 2018*]. Exceptionally high temperature values were recorded in autumn 2017 in Crimea: daytime temperatures were warmer than average (+17 - +18^{0}C) for September across most of Crimea [*The report…, 2018*]. Prolonged exposure to extreme heat can exacerbate preexisting chronic conditions, such as cardiovascular diseases [*De Blois J et al., 2015; Liu C et al., 2015*], while respiratory tract is more affected by cold [*D'Amato G et al., 2014*]. In addition, epidemiologic data on incidence of acute cardiovascular events like heart attack, stroke and heart failure provides strong evidence to support this assertion [*De Blois J et al., 2015; Shartova N et al., 2018*]. On the other hand, the cardiovascular system (CVS) is one of the most important systems for the body [*Senan P, 2012*]. It provides an adequate blood circulation to the vital organs for better adaptation to climate variability, including high temperatures. Subsequently, decompensation occurs if CVS or other vital systems fail to adapt to the changing environmental conditions. Attempts to restore human adaptive capacity should set the initial focus on efforts for cardiovascular risk factor reduction beside rationale pharmacological interventions at a later stage. Climate change triggers simultaneous changes in central nervous (CNS) and autonomic nervous systems (ANS) to insure appropriate CVS adjustment [*Padhy S et al., 2015; Münzel T et al., 2017*]. The central thermoregulatory system receives signals related to changes in environmental temperature through thermoreceptors triggering the physiological changes. But the capacity of the human body to thermoregulate may be exceeded on a regular basis and the long term impacts of climate change on a person's emotional and psychological state can lead to significant discomfort, affect higher mental functions (HMF) and as a result labor productivity decreases [*Rice S, McIver L, 2016*]. Researchers have proposed that climate change affects the habitual behaviors that underlie personality traits [*Clayton S et al., 2015*]. Climate change exposes pre-existing psychological vulnerabilities [*Shiue I et al., 2015*]. Some studies suggest that rising temperature might negatively impact mental health [*Padhy S et al., 2015; Hayes K, Poland B, 2018*]. Although researchers have suggested that global warming affect both the onset and severity of cardiovascular and mental disorders at a population level, but the impact of climate change on higher mental activities and ANS remains relatively unexplored. The identified research gaps regarding the health consequences of climate change enables deeper assessment that can be a starting point for understanding the opportunities for possible solutions. Thereby the assessment of higher mental activities and cardiac regulation related to climate change with high temperature exposure will provide an opportunity to evaluate factors that regulate each component of risk.

MATERIAL AND METHODS

Forty-five individuals (18 males and 27 females; 18.7±0.6 year old) with no evidence or history of chronic disease and not on any medications were enrolled into the study while undergoing a diagnostic assessment in laboratory of medical and environmental monitoring with risk assessment at Medical Academy named after S.I. Georgievsky (Simferopol, Russian Federation). All participants had signed the informed consent and all procedures conformed to the Declaration of Helsinki. The study procedures were approved by the university ethics committee (protocol No.5, 19 February of 2015).

Monitoring of cardiovascular parameters, ANS and higher mental activities examination was conducted in September 2017 (7 days) and February 2018 (10 days). All recordings were performed from 9.00 to 12.00 after getting acquainted with the rules of procedure.

HMF were assessed by 4 standard tests: Schulte tables [*Rubinstein S, 1999*] and Anisimov-Bourdon test [*Raygorodskiy D, 2011*] to assess the ability to concentrate for long periods of time, speed, and accuracy; "Wellbeing-Activity-Mood" questionnaire for evaluation of psycho-emotional and behavioral status [*Doskin V, 1973*] and State-Trait Anxiety Inventory (STAI) Yu. Hanin modification [*Raygorodskiy D, 2011*].

The principle of the Anisimov-Bourdon test is to strike out or underline stimuli very similar in shape (letters "K" and "P") within rows of letters arranged randomly on a sheet of paper. The aim is to mark without mistakes as many submitted letters as possible in the given time interval (5 minutes). On the basis of performance we evaluated the performance capacity (PC) of an individual as equal to letters proceeded altogether within 5 minutes and his/her accuracy using the formula:

$$A = \frac{m}{n} \cdot 100\%$$

where A – accuracy, n – number of letters to be marked altogether, m – number of letters underlined without mistakes in the given time interval.

Schulte tables (grids with randomly distributed numbers) were used to determine the time (in seconds) that the individuals spend to find all the numbers (from 1 to 25) on a sheet of paper in 5 trials [*Rubinstein S, 1999*]. Other measurements included: work efficiency (WE) = $0.2\cdot(t_1 + t_2 + t_3 + t_4 + t_5)$, where t_i - completion time of table i; work warming-up (WU) = t_1/WE; psychological stability (PS) = t_4/WE.

Assessment of autonomic regulation of cardiac activity was performed by heart rate variability (HRV) measurement, where five-minute HRV recordings by three-lead electrocardiography ("CARDIO US-01", "Mida", Ukraine) were obtained at rest in supine position and during 2 standard cardiovascular reflex tests [*Ewing D, 1992; Spallone V et al., 2011*]. One of these tests assesses parasympathetic function: heart rate responses to deep breathing was measured from a series of successive deep breaths at a rate of 6 breaths per minute (5 *sec* inspiration, 1 *sec* pause, 5 *sec* expiration, 1 *sec* pause) and the other evaluates sympathetic function: HRV responses in lying to standing (orthostatic) test. Time-domain HRV and frequency-domain HRV indexes were analyzed. Time-domain HRV indexes include the variation range (dX), the mean of all normal-to-normal (NN) RR intervals (RRNN, *ms*), the standard deviation of NN intervals (SDNN, ms^2), percentage of adjacent RR intervals with a difference of duration greater 50 ms (PNN50, %), and the root mean square successive difference of the RR interval (RMSSD, *ms*), triangular index (TINN – triangular interpolation of NN intervals). Frequency-domain HRV indexes include low frequency power (LF, ms^2), high frequency power (HF, ms^2), very low frequency power (VLF, ms^2) and total power (TP, ms^2). Normalized low (LFn) and high (HFn) frequency powers, and ratio (LF/HF) were also calculated [*Malik M et al., 1996*].

Meteorological data for warm and cold seasons (September and February) were downloaded from the weather station with online resource (https://rp5.ru). Meteorological data were reported as 3-hour average measures of the

- * T – air temperature, °*C*;
- * Po – local pressure at the station level, *mmHg;*
- * P – pressure brought down to sea level, *mmHg;*
- * Pa – barometric tendency – pressure changes for the last 3 *hours*, *mmHg*;
- * U – relative air humidity at 3 *m* height, *%*;
- * Ff – wind velocity (the 10-*min* average wind speed at 10-12 *m* height right before the observation period, *m/s*);
- * N – total cloudiness at the Simferopol weather station (WMO index 33955), *%*.

The study utilized following indices:

- ➢ Po_{min}/day – minimum local pressure, *mmHg*;
- ➢ Po_{max}/day – maximum local pressure, *mmHg*;
- ➢ P_{min}/day – minimum pressure brought down to sea level, *mmHg*;
- ➢ P_{max}/day – maximum pressure brought down to sea level, *mmHg*;
- ➢ T_{min}/day – minimum daily temperature, °*C*;

- ➢ T_{max}/day – maximum daily temperature, °*C*;
- ➢ U_{min}/day – minimum relative air humidity, %;
- ➢ U_{max}/day – maximum relative air humidity, %.

Data are expressed as the mean ± SD, median (Me), 25 and 75 percentile. According to Kolmogorov-Smirnov and Lilliefors normality test examined variables were not normally distributed. Differences between the parameters, groups have been tested with the non-parametric tests (Mann-Whitney-U, Wilcoxon) and Spearman's correlation coefficient was used to measure the relationship of the variables. Data were considered to be statistically significant at p values of less than 0.05. Statistical analysis was performed using a commercial software package Statistica 6.0 (StatSoft, 2001).

RESULTS AND DISCUSSION

Medians of meteorological data during the monitoring (Fig. 1) in September based on temperature and bioclimatic indices were identified as heat waves: T_{max}/day = 28.6±3.9 ^{0}C; T_{min}/day = 17.6±1.5 ^{0}C; Po=742.63±1.4 *mmHg*; N = 80±1,3%, and in February were within normal ranges for the Crimean peninsular: T_{max}/day = 5.5±5.2^{0}C; T_{min}/day = =-1.1±2.6^{0}C; P_o=745.6±6.9 *mmHg*; N = 100±1.5%.

Results of HMF weather sensitivity assessment in different seasons suggest that all the parameters of voluntary attention, wellbeing, levels of anxiety and mood in volunteers were within the age norm [*Rubinstein S, 1999*] with no significant seasonal difference except for the t_3 time in Schulte tables between September and February (34.80 vs 28.88; p=0.01). Both wellbeing and mood were significantly better in September than in February (both p<0.01) and anxiety levels were significantly higher in winter (29.0 vs 39.5 p≤0.001, U-test Mann-Whitney).

Correlation analyses among autumn and winter registrations shown in Table 1 revealed significant associations between parameters of voluntary attention with N and Ff in September and with most of the meteorological factors in February ($0.30 \leq r_s \leq 0.48$; $0.05 \leq p \leq 0.004$).

As shown in table 2, psychoemotional characteristics displayed generally direct relations with meteorological factors mostly in September.

Most of the associations with meteorological factors (temperature and pressure) and anxiety were revealed during observation that coincided with the heat wave event in September 2017.

HRV assessed with both time and frequency domain approaches demonstrated that all the param-

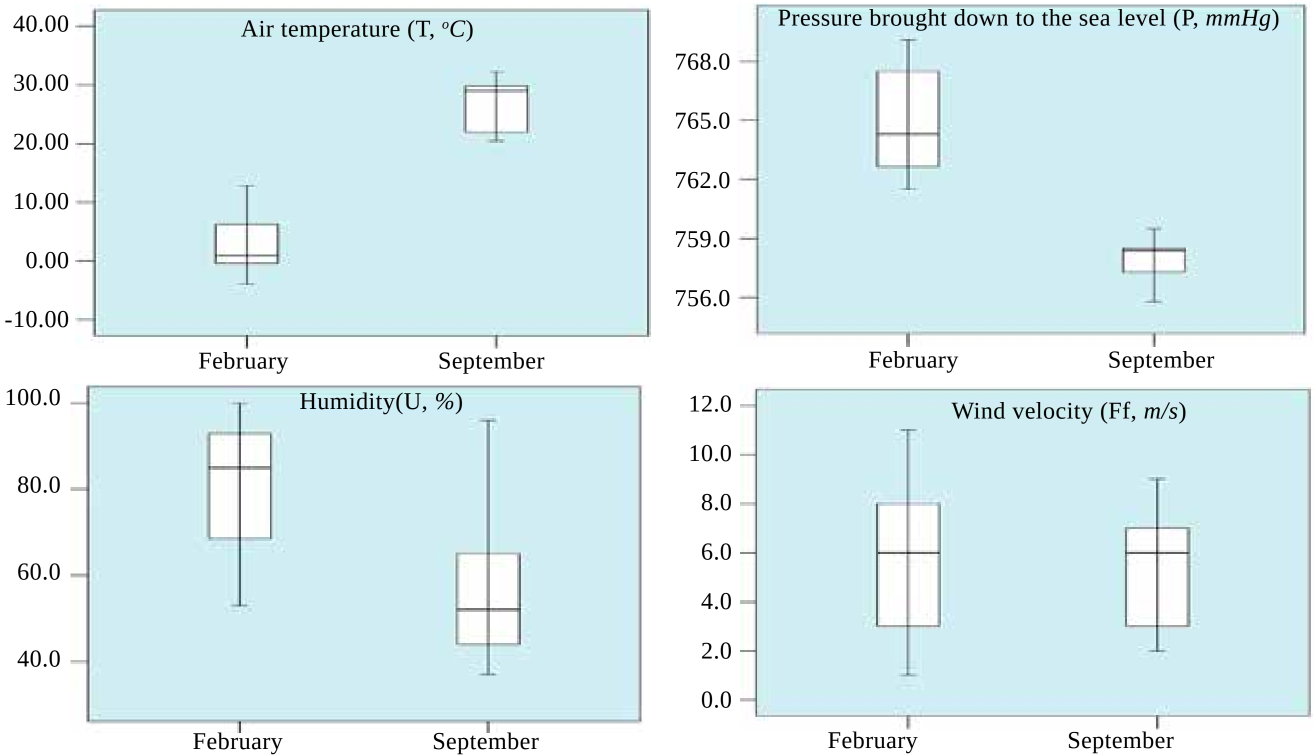

FIGURE 1. *Boxplot of the meteorological data (air temperature – T; pressure brought down to the sea level – P; humidity – U; wind velocity – Ff) in Simferopol in September 2017 and February 2018. The p-value is calculated using the paired Mann–Whitney test (p < 0,05 was considered significant).*

TABLE 1

Correlations (r_s) between characteristics of voluntary attention and meteorological factors in September and February ($p<0.05$)

Meteorological factors	Registration	Characteristics of voluntary attention						
		t_1	t_2	t_4	t_5	WU	PS	WE
Total cloudiness	September	0.33 p=0.03				0.48 p=0.001	-0.35 p=0.02	
Total cloudiness	February		-0.39 p=0.01	-0.34 p=0.02				-0.3 p=0.05
Wind velocity			0.42 p=0.006	0.46 p=0.002	0.35 p=0.02			0.43 p=0.004
Air temperature							0.3 p=0.05	
Po						0.3 p=0.05		

NOTES: *t_1-t_5 – completion time of Schulte tables in seconds; WE – work efficiency; WU – work warming-up; PS – psychological stability; Po – local atmospheric pressure at the station level.*

TABLE 2

Correlations (r_s) between psychoemotional characteristics and meteorological factors in September and February ($p<0.05$)

Meteorological factors	Registration	Psychoemotional characteristics			
		Anxiety	Wellbeing	Activity	Mood
N	September			0.37; p=0.03	
T_{max}/day		-0.37; p=0.03			
T_{min}/day		-0.36; p=0.001			
P			0.45; p=0.01		0.44; p=0.01
P_{max}/day		0.33; p=0.04			
Po			0.37; p=0.03		0.37; p=0.03
U			0.49; p=0.005		0.37; p=0.03
Ff			0.44; p=0.01		
N	February			0.35; p=0.04	
U		-0.48; p=0.04			

NOTES: *N – total cloudiness; T_{max}/day – maximum daily temperature; T_{min}/day – minimum daily temperature; P – pressure at the sea level; P_{max}/day – maximum pressure brought down to sea level; Po – local atmospheric pressure at the station level; U – humidity; Ff – wind velocity.*

eters were within normal ranges [*Malik M et al., 1996; Bayevskij R et al., 2002; Shlyk N, 2009*] both at rest and during standard cardiovascular reflex tests [*Shields R, 2009; Patel K et al., 2016*].

For HRV parameters, only LF showed significant seasonal differences with its values significantly higher in September (1307.0±619.59 ms^2) than in February (936.00±441.77 ms^2) that may have been mediated by stress due to heat wave exposure and is associated with reduced parasympathetic activity.

At rest only in February significant associations between meteorological factors and HRV measures were observed using Spearman correlation (table 3). Furthermore tables 4 and 5 show that several meteorological factors were significantly associated with HRV measures during cardiovascular reflex tests both in autumn and in winter.

The relationships of the dX, RMSSD, pNN50 at rest and humidity suggest that sympathetic nervous activity was activated with involvement of higher centers by the increased humidity. This data is supported by the positive associations between

TABLE 3

Correlations (r_s) between HRV indexes at rest and meteorological factors in February ($p<0.05$)

Meteorological factors	HRV indexes							
	dX	AMo	TI	RMSSD	pNN50	LFn	HFn	LF/HF
Humidity	-0.37 (0.03)	0.34 (0.04)	0.35 (0.04)	-0.34 (0.04)	-0.34 (0.04)			
Wind velocity						-0.39 (0.02)	0.39 (0.02)	-0.38 (0.02)

Note: *dx - variation range; AMo - amplitude of mode; TI - tension index; RNSSD the root mean sguare sucessive difference of the RR interval; pNN50% – percentage of adjacent RR intervals with a difference of duration greater 50 ms; LF – low frequency power; HF – high frequency power; LFn and HFn – normalized low (LFn) and high (HFn) frequency powers.*

AMo and tension index (TI) or stress index calculated by the following formula: TI = AMo/2Mo • dX [*Bayevskij R et al., 2002*].

Identified associations between HRV indexes and humidity were suggestive for increased sympathetic activity and involvement of suprasegmental centers into the autonomic regulation during both cardiovascular reflex tests and these effects were similar in September and February. Of all the studied meteorological parameters humidity was found to be the most influential factor during deep breathing test.

No effects of temperature using the Spearman correlation were observed for HRV recordings at rest and during February registration. Only for HRV during cardiac reflex tests recorded in September we observed individual significant associations. Negative correlations between the temperature and HRV parameters related to the cardiac cycle duration (Mo, Me, RRNN) indicate an increase in sympathetic activity as temperature increases during the deep breathing test (Table 4). Additionally the index of centralization (IC = (HF + LF) / VLF) was also calculated to evaluate the ANS balance beside the assessment of vagosympathetic index (LF / HF). IC characterizes the contribution of central (suprasegmental) mechanisms to the regulation of cardiac activity [*Baevskij R, 2004*]. Positive association of air temperature with IC was established, that along with the above mentioned correlations can be interpreted as an increase in the activity of the central control loop in this cohort during September, when heat waves were observed.

TABLE 4

Correlations (r_s) between HRV indexes during cardiovascular reflex tests and meteorological factors in September ($p<0.05$)

HRV parameters	Meteorological factors	r_s	p-value
Deep breathing test			
Mo	T_{max}/day	-0.31	0.04
Me		-0.30	0.04
RRNN		-0.30	0.04
Me	Pa	0.30	0.04
LF/HF	U_{min}/day	0.30	0.04
Orthostatic test			
VLF	T	-0.42	0.00
IC		0.46	0.01
IC	T_{min}/day	0.38	0.01
VLF	Pa	0.35	0.02
	Po_{max}/day	0.34	0.02
	P_{max}day	0.34	0.02
IC	U	-0.49	0.00
	Po_{max}/day	-0.35	0.02
	P_{max}/day	-0.35	0.02
	U_{min}/day	-0.40	0.01

Note: *T – air temperature; T_{max}/day – maximum daily temperature; T_{min}/day – minimum daily temperature; Pa – barometric tendency; U – humidity; U_{min}/day – minimum relative air humidity; Po_{max}/day – maximum local pressure; P_{max}/day – maximum pressure brought down to sea level; RRNN – the mean of all normal-to-normal (NN) RR intervals; Mo – mode of RRNN; Me – median of RRNN; LF – low frequency power; HF – high frequency power; VLF – very low frequency power; IC – index of centralization.*

Table 5

Correlations (r_s) between HRV indexes during cardiovascular reflex tests and meteorological factors in February ($p<0.05$)

HRV parameters	Meteorological factors	r_s	p-value
Deep breathing test			
Mo	P	0.46	0.01
Me		0.40	0.02
RRNN	P	0.43	0.02
	U	-0.33	0.04
	U_{min}/day	-0.33	0.04
RMSSD	U	-0.41	0.01
	Ff	0.34	0.04
pNN50	U	-0.46	0.00
VLF	T	-0.38	0.02
	T_{min}/day	-0.35	0.04
	T_{max}/day	-0.45	0.01
	Po_{max}/day	-0.37	0.02
	P_{max}/day	-0.33	0.04
	U_{min}/day	0.35	0.03
LFn	U	0.44	0.01
	Ff	-0.43	0.01
HF	U	-0.41	0.01
	Ff	0.44	0.01
HFn	U	-0.44	0.01
	Ff	0.43	0.01
LF/HF	U	0.43	0.01
	Ff	-0.45	0.01
IC	T	0.35	0.04
	T_{max}/day	0.36	0.03
	U_{min}/day	-0.35	0.03
Orthostatic test			
TINN	Pa	-0.36	0.04
LFn	U	0.43	0.01
HF	Pa	-0.36	0.04
HFn	U	-0.43	0.01
LF/HF		0.43	0.01

Note: T – air temperature; T_{max}/day – maximum daily temperature; T_{min}/day – minimum daily temperature; P – pressure brought down to sea level; Pa – barometric tendency; U – humidity; U_{min}/day – minimum relative air humidity; Po_{max}/day – maximum local pressure; P_{max}/day – maximum pressure brought down to sea level; Ff – wind velocity; RRNN – the mean of all normal-to-normal (NN) RR intervals; Mo – mode of RRNN; Me – median of RRNN; RMSSD – the root mean square successive difference of the RR interval; pNN50% – percentage of adjacent RR intervals with a difference of duration greater 50 ms; TINN – triangular interpolation of NN intervals; LF – low frequency power; HF – high frequency power; VLF – very low frequency power; IC – index of centralization; LFn and HFn – normalized low (LFn) and high (HFn) frequency powers.

Atmospheric pressure as shown in tables 4 and 5 was also among major important factors based on the number of correlations revealed. It had opposite effects on HRV during cardiovascular reflex tests. During orthostatic test negative associations with HF and TINN indicated decreased HRV as atmospheric pressure increases. Negative correlation of atmospheric pressure with IC indicates an increased activity of suprasegmental centers of the autonomic regulation as atmospheric pressure decreases. During the deep breathing test, the associations (Mo, Me, RRNN) were positive, suggesting an increase in parasympathetic activity.

Heart rate variability analysis as a non-invasive method is used to assess the cardiac autonomic control under physiological and pathological conditions [*Malik M et al., 1996*]. Numerous studies reported that decreased HRV is associated with cardiovascular morbidity [*Schuster A et al., 2016; Kubota Y et al., 2017*]. Revealed changes could be explained by the following mechanisms: reduced ANS tone, insufficient baroreflex responsiveness as a result of decreased HRV that could be linked to increased air humidity and temperature. The alterations in cardiac autonomic functions assessed by the HRV method could be used to identify the individuals at a greater risk of cardiovascular morbidity and mortality brought about by climate changes.

Conclusion

The findings of this preliminary study indicate that heat stress can be assessed using heart rate variability and clinical examination of higher mental functions. Use of cardiovascular reflex tests improves the heat stress assessment and the identification of individuals at risk. The results in the examined cohort confirm the heat stress impact on healthy individuals: higher air temperature in autumn was associated with low emotional stability and lower HRV that could be the potential risk of cardiovascular diseases.

Acknowledgement: *The research work was supported by the Fundamental Research Program of the Russian Academy of Sciences Presidium in the framework of the project "Developing Recommendations for the Adaptation of Populations of Different Age Groups to Heat Waves", 2018-2020.*

REFERENCES

1. [The report about the state and protection of the environment on the territory of the Republic of Crimea in 2017] [Published in Russian]. Simferopol, 2018. 585 p.
2. *Baevskij RM.* [Analyses of heart rate variability: history and philosophy, theory and practice] [Published in Russian]. Clinical Informatics and telemedicine. 2004; 1(1): 54-64.
3. *Bardin MJ, Rankova EYa, Platova TV, Samokhina OF, Aleshina MA., et al.* [A report on climate features on the territory of the Russian federation in 2017] [Published in Russian]. Moscow. 2018. 69p.
4. *Bayevskij RM, Ivanov GG, Chireykin LV, Gavrilushkin AP, Dovgalevsky PY., et al.* [HRV analysis under the usage of different electrocardiography systems (part 1)] [Published in Russian]. Vestn. aritmolog. 2002; 24: 65-87.
5. *Clayton S, Devine-Wright P, Stern PC, Whitmarsh L, Carrico A., et al.* Psychological research and global climate change. Nature climate change. 2015; 5: 640-646.
6. *D'Amato G, Cecchi L, D'Amato M, Annesi-Maesano I.* Climate change and respiratory diseases. Eur Respir Rev. 2014; 23(132): 161-169.
7. *De Blois J, Kjellstrom T, Agewall S, Ezekowitz JA, Armstrong PW., et al.* The Effects of Climate Change on Cardiac Health. Cardiology. 2015; 131: 209-217.
8. *Doskin VA, Lavrenteva NA, Miroshnikov MP, Sharai VB.* [Test differentiated self-estimation of the functional state] [Published in Russian]. Psychology Issues. 1973; 6: 141-145.
9. *Ewing DJ.* Analysis of heart rate variability and other noninvasive tests with special reference to diabetes mellitus. Autonomic failure. 3rd ed. Oxford: Oxford University Press. 1992. p. 312e33.
10. *Field CB, Barros VR, Dokken DJ, Mach KJ, Mastrandrea MD., et al.* IPCC, 2014: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [(eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. 2014. 1132p.
11. *Grigoryev KI, Povazhnaya EL.* [The problem of increased meteosensitivity in children and adolescents] [Published in Russian]. Russian Bulletin of Perinatology and Pediatrics. 2018; 63(3): 84-90.
12. *Hales S, Kovats S, Lloyd S, Campbell-Lendrum D., et al.* Quantitative risk assessment of the effects of climate change on selected causes of death, 2030s and 2050s. Geneva: World Health Organization. 2014. 128p.
13. *Hayes K, Poland B.* Addressing mental health in a changing climate: incorporating mental health indicators into climate change and health vulnerability and adaptation assessments. Int J Environ Res Public Health. 2018; 15(9): E1806.
14. *Kim KH, Kabir E, Ara Jahan S.* A review of the consequences of global climate change on human health. J. Environ. Sci. Health C. Environ. Carcinog. Ecotoxicol. Rev. 2014; 32(3): 299-318.
15. *Kobysheva NV, Klyueva MV.* [Modern problems of medical climatology] [Published in Russian]. Proceedings of the Main Geophysical Observatory named after A.I. Voeikova. 2016; 581: 103-115.
16. *Kubota Y, Chen LY, Whitsel EA, Folsom AR.* Heart rate variability and lifetime risk of cardiovascular disease: the Atherosclerosis Risk in Communities Study. Ann Epidemiol. 2017; 27(10): 619-625.e2.
17. *Liu C, Yavar Z, Sun Q.* Cardiovascular response to thermoregulatory challenges. American journal of physiology. Heart and circulatory physiology. 2015; 309(11) H1: 793-812.
18. *Malik M, Bigger JT, Camm AJ, Kleige RE, Malliani A., et al.* Heart rate variability: Standards of measurement, physiological interpretation, and clinical use. European heart journal. 1996;17(3): 354-381.
19. *Münzel T, Sørensen M, Gori T, Schmidt FP, Rao X., et al.* Environmental stressors and cardio-metabolic disease: part II-mechanistic insights. Eur Heart J. 2017; 38(8): 557-564.

20. *Orru H, Ebi KL, Forsberg B.* The interplay of climate change and air pollution on health. Curr Environ Health Rep. 2017; 4(4): 504-513.
21. *Padhy SK, Sarkar S, Panigrahi M, Pau S.* Mental health effects of climate change. Indian J Occup Environ Med. 2015; 19(1): 3-7.
22. *Patel K, Rössler A, Lackner HK, Trozic I, Laing C., et al.* Effect of postural changes on cardiovascular parameters across gender. Medicine (Baltimore). 2016; 95(28): e4149.
23. Raygorodskiy DY. [Practical psychodiagnostics. Methods and tests] [Published in Russian]. M.: bachrach M. 2011. 672p.
24. *Rice SM, McIver LJ.* Climate change and mental health: Rationale for research and intervention planning. Asian J Psychiatr. 2016; 20: 1-2.
25. *Rubinstein SY.* [Experimental methodology pathopsychology] [Published in Russian]. Series The world of psychology. Moscow, Publishing House EKSMO-press. 1999. 448 p.
26. *Schuster AK, Fischer JE, Thayer JF, Mauss D, Jarczok MN.* Decreased heart rate variability correlates to increased cardiovascular risk. Int J Cardiol. 2016; 203: 728-30.
27. *Senan PM.* The relation between the variety of stress and arrhythmias. The New Armenian Medical Journal. 2012; 6(1): 60-67.
28. *Shartova N., Shaposhnikov D., Konstantinov P., Revich B.* Cardiovascular mortality during heat waves in temperate climate: an association with bioclimatic indices. International journal of environmental health research. 2018; 28(5): 522-534.
29. *Shields RW.* Heart rate variability with deep breathing as a clinical test of cardiovagal function. Cleve Clin J Med. 2009;76 (Suppl 2): S37-40.
30. *Shiue I, Perkins DR, Bearman N.* Physically equivalent temperature and mental and behavioural disorders in Germany in 2009-2011. J Ment Health. 2016; 25(2): 148-153.
31. *Shlyk NI.* [The heart rate and regulation type of children, teenagers and sportsmen] [Published in Russian]. Izhevsk, Udmurt university. 2009. 259p.
32. *Spallone V, Bellavere F, Scionti L, Maule S, Quadri R., et al.* Recommendations for the use of cardiovascular tests in diagnosing diabetic autonomic neuropathy. Nutr Metab Cardiovasc Dis. 2011; 21(1): 69-78.
33. *Trombley J, Chalupka S, Anderko L.* Climate Change and Mental Health. Am J Nurs. 2017; 117(4): 44-52.
34. *Vicedo-Cabrera AM, Sera F, Guo Y, Chung Y, Arbuthnott K., et al.* A multi-country analysis on potential adaptive mechanisms to cold and heat in a changing climate. Environment international. 2018; 111: 239-246.
35. *Watts N, Adger WN, Ayeb-Karlsson S, Bai Y, Byass P., et al.* The Lancet Countdown on health and climate change: from 25 years of inaction to a global transformation for public health. The Lancet. 2017; 391(10120): 581-630.