

Прогнозування розвитку захворювань тканин пародонта

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Вступ. Захворювання тканин пародонта – одна з найпоширеніших стоматологічних патологій, яка серед молодих людей зустрічається з частотою від 60 % до 99 %. Тому актуальною є проблема пошуку нових ланок патогенезу, причин зростання поширеності захворювань тканин пародонта, а також ефективних методів їх ранньої діагностики та профілактики.

Мета – встановити можливість використання індивідуальних стоматологічних та психофізіологічних особливостей для прогнозування розвитку захворювань тканин пародонта.

Матеріали та методи. Було обстежено 156 студентів віком 18-23 років без системних захворювань та визначено особливості гігієни порожнини рота та харчування. Також досліджували пройшли стоматологічне обстеження, психологічне тестування та оцінку індивідуальних типологічних особливостей вищої нервової діяльності та автономної регуляції. Модель статистичного прогнозування була розроблена з використанням нейронних мереж.

Результати. Були розроблені дві нейронні мережі з використанням оптимальних предикторів із даних стоматологічного анамнезу та огляду, психологічного тестування, параметрів вищої нервової діяльності та аналізу варіабельності серцевого ритму. Діагностична чутливість першої прогностичної моделі становила 83,33 %, а специфічність – 92,31 %. Друга модель характеризувалася чутливістю 90,00 % та специфічністю 78,57 %.

Висновок. Метод моделювання з використанням нейронних мереж на основі індексної оцінки стану твердих тканин зубів, рівня гігієни порожнини рота та оцінки психофізіологічних особливостей дозволяє ефективно прогнозувати ризик розвитку захворювань тканин пародонта у молодих людей.

Ключові слова: гінгівіт, молоді люди, прогнозування, нейронна мережа.

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Prediction of the development of periodontal disease

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Introduction. Periodontal tissue disease is one of the most common dental pathologies, which among young people occurs with a frequency of 60% to 99%. Therefore, the problem of finding new links in the pathogenesis, the reasons for the growing prevalence of periodontal disease, as well as effective methods for its early diagnosis and prevention, is relevant.

Objectives. Establish the possibility of using individual stomatological and psychophysiological features to predict the development of periodontal disease.

Materials and methods. 156 students aged 18-23 years old without systemic diseases were surveyed for some features of oral hygiene and nutrition. Also the study subjects underwent a dental examination, psychological testing and the assessment of individual typological features of higher nervous activity and autonomous regulation. The model for statistical prediction were designed using neural networks.

Results. Two neural networks were designed with the best predictors among dental history and examination, psychological testing, parameters of higher nervous activity and heart rate variability analysis. The diagnostic sensitivity of the first prognostic model was 83.33 % and the specificity was 92.31 %. The second model was characterized by 90.00 % sensitivity and 78.57 % specificity.

Conclusion. The method of modeling using neural networks based on the index assessment of the condition of teeth hard tissues, the level of oral hygiene and the evaluation of psychophysiological features can effectively predict the risk of periodontal disease development in young people.

Keywords: gingivitis, young people, prediction, neural network.

Introduction

World medicine pays more and more attention to prevention and personalized approach in treatment and prognosis. Modern technological support and digitalization allow to realize it [1].

Periodontal tissue disease is one of the most common dental pathologies, which among young people occurs with a frequency of 60% to 99% [2]. Therefore, the problem of finding new links in the pathogenesis, the reasons for the growing prevalence of periodontal dis-

ease, as well as effective methods for its early diagnosis and prevention, is relevant. There is ample evidence in the scientific literature that psychophysiological features can reflect the state of adaptive systems and the ability to respond to various harmful stimuli, and methods for assessing them are non-invasive and easily accessible [3,4]. However, there is a lack of a comprehensive assessment of psychophysiological features in people with periodontal disease, which would allow on their basis to predict the development of periodontal disease and its prevention in young people.

Currently, computer modeling and forecasting are widely used to predict various pathologies [1,5–10]. One of the increasingly popular prognostic methods is modeling using artificial neural networks, based on principles similar to the functioning of the nervous system. This method has proven to be effective in various fields of medicine. The review [11] provides data on the effective use of artificial neural networks in the organization of medical services. It is used to predict the development of tuberculosis and neuroblastoma [12,13]. In addition, the use of artificial neural networks to predict outbreaks of COVID-19 is described [14]. However, in scientific sources of recent years there is no data on the application of this approach in dentistry.

Therefore, in our opinion, it is advisable to study the possibility of using artificial neural networks to predict the development of periodontal disease in young people based on psychophysiological parameters.

The aim of study was to establish the possibility of using individual stomatological and psychophysiological features to predict the development of periodontal disease.

Materials and methods

The research was conducted at the Laboratory of Psychophysiological Research of the Department of Physiology, Bioethics and Biosafety of the I. Horbachevsky Ternopil National Medical University of the Ministry of Health of Ukraine (Certificate № 003/18) and the Department of Therapeutic Dentistry of the same university. The work adhered to the bioethical norms of the World Medical Association Declaration of Helsinki «Ethical Principles of Medical Research Involving Human Subjects» (adopted by the 18th

World Medical Association General Assembly, amended in October 2013), the International Code of Medical Ethics, and the laws of Ukraine confirmed by the decision of the commission on bioethics of I. Horbachevsky Ternopil National Medical University of the Ministry of Health of Ukraine, protocol №62 dated January 11, 2021.

The informed consent was received from all study participants.

156 students of the I. Horbachevsky Ternopil National Medical University aged 18-23 years old without systemic diseases were selected for the study. All subjects were divided into two groups: the main – with the presence of periodontal tissue lesions (84 people); control – without periodontal pathology (72 people). A survey was conducted, which included the frequency of brushing teeth, the use of interdental cleaners, the rigidity of the brush, the frequency of preventive examinations and professional oral hygiene, diet regularity, frequency of consumption of fruits, vegetables and foods rich in carbohydrates or proteins. According to the results of the dental examination, the index of tooth and surface caries intensity (CI_t, CI_s), hygienic indices by Silness-Low (SL), Stallard (St), Green-Vermilion (GW) and retention index (RI) were calculated [15]. The gingival biotype was determined using a special set of tools «Colorvue Biotype Probe» (Hu-Friedy, USA) [16].

Psychological features were determined using the method of well-being, activity and mood evaluation by V. Doskin and N. Lavrentieva, Spielberger's «The State-Trait Anxiety Inventory», adapted by Yu. Khanin, and a clinical questionnaire for the detection and evaluation of neurotic states by K. K. Yakhin and D. M. Mendelevich (1978) [17-18].

Individual typological features of higher nervous activity were evaluated using the express methods of M. V. Makarenko using the computer system «Diagnost-1M», developed by M. V. Makarenko and V. S. Lyzogub [19].

Features of autonomic regulation were determined using a mathematical analysis of heart rate variability, which included spectral analysis and cardiointervalography according to R. M. Baevsky [20].

Statistical processing involved normalization of data, selection of predictors based on analysis of averages using Student's T-test for data with normal distribution and Mann-Whitney rank U-test for other data. Nominal values were chosen using Pearson's chi-square or Fisher-Freeman-Halton exact test. The models for statistical prediction were designed using neural networks. The models were evaluated for sensitivity and specificity.

Results

According to the questionnaire, a significant difference between the study groups were found only in the frequency of brushes of different stiffness use ($p=0.0043$). Among people with periodontal disease, the majority used medium toothbrushes (86.30 %). 8.22 % of respondents used soft toothbrushes and 5.48 % used hard ones. In the control group, 62.96 % of students used medium toothbrushes, which is 1.4 times less than in the main group. 12.96 % of young people used soft toothbrushes, and 24.07 % - hard, which is 1.6 times and 4.4 times lower than those with periodontal disease (fig. 1). In pairwise comparison, a significant difference in the ratio of frequencies of medium and hard toothbrushes usage ($p = 0.0014$) was recorded. These data show that young people without periodontal disease were significantly more likely to use hard toothbrushes for personal oral hygiene.

According to the objective dental examination, a statistically significant difference between the study groups was recorded for the assessment of soft plaque amount using the SL index. In the examined with the presence of periodontal

lesions, 1.3 times higher values of this index were observed compared to the control group ($p=0.0014$). There was also a significant increase in the hygienic index of St in the main group by 1.3 times compared with those examined without periodontal pathology ($p=0.0048$). The data are supported by the GW, which estimates the amount of soft and hard dental plaque comprehensively. In particular, significantly higher values were found in the representatives of the main group, which are 1.6 times the value of this index in the control group ($p=0.0000$) (Table 1).

According to the results of the RI calculation which actually takes into account the condition of the teeth hard tissues and the presence of calculus, the average value of this index in the examined with periodontal diseases was 2.8 times higher than in the control group ($p=0.0000$) (Table 1).

Analysis of the results of determining the gingival biotype showed that in people with periodontal lesions the majority had thin and thick biotypes with a predominance of thin (41.10 % and 26.03 %, respectively). The medium gingival biotype was found in 24.66 % of the examined in main group. The least common biotype among young people with periodontal disease was very thick – 8.22 %. In the control group, more than a third part of the subjects had a thick gum biotype – 31.48 %, which is 1.3 times more than in the main group. The medium biotype was registered in 33.33 % of cases. Thin and very thick gingival biotypes were the least common. The first was found in 12.96 % of periodontally healthy young people, and the second – in 22.22 %. That is, a thin biotype among the representatives of

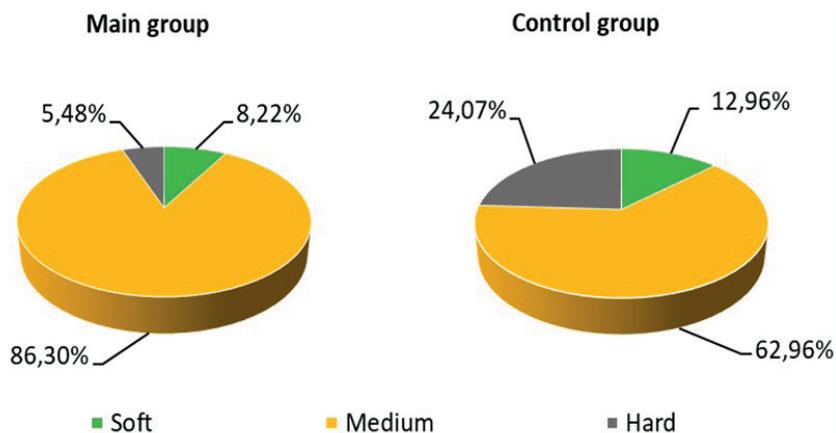


Figure 1. The usage of brushes of different stiffness in the study groups

Table 1

Dental indices in research groups (points)

Index	Main group (n=84)		Control group (n=72)		p
	M	m	M	m	
CI _t	7,45	0,42	6,24	0,50	0,0825
CI _s	8,84	0,54	7,28	0,68	0,0526
SL	1,14	0,05	0,91	0,04	*0,0014
St	0,97	0,05	0,75	0,05	*0,0048
GW	1,21	0,07	0,75	0,05	*0,0000
RI	0,25	0,02	0,09	0,01	*0,0000

Note:
* – significant difference between the values of the main and control groups

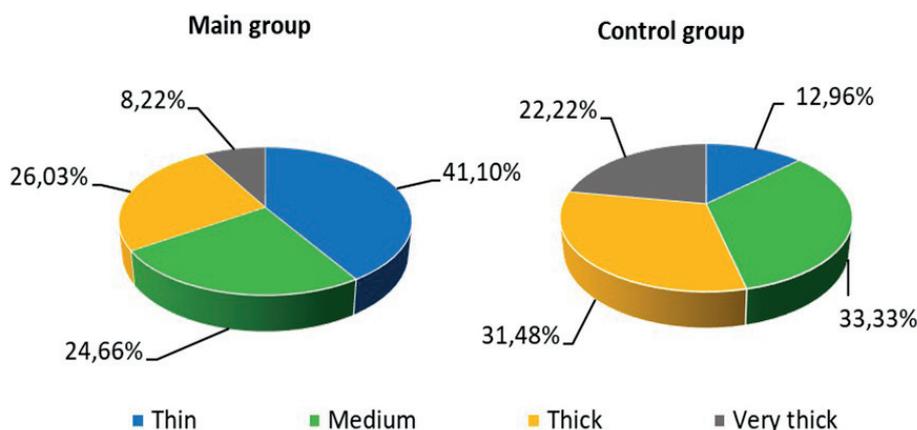


Figure 2. Prevalence of different gingival biotypes in main and control groups

the control group was 3.2 times less common compared to the main group, and very thick – 2.7 times more common (fig. 2).

There was a significant difference in the frequency distribution of gingival biotypes between the main and control groups (p=0.0031). In particular, a statistically significant difference was observed in next pairs of biotypes – thin/thick (p=0.0101), thin/medium (p=0.0051) and thin/very thick (p=0.0005). This indicates the greatest difference in the study groups between the frequency of the thin gingival biotype in relation to others.

There was no statistically significant difference in the results of the well-being and mood assessment (p=0.1638 and p=0.1300, respectively). However, the level of activity in individuals with periodontal lesions was 9.74 % lower than in the control group (p=0.0003) (Table 2).

Significant differences between the main and control groups were found in the values of trait

anxiety (TA). In subjects with periodontal disease, there was an increase in the level of TA by 12.12 % compared with the control group (p=0.0107). In periodontally healthy subjects, the mean values of TA can be attributed to a high level, while in the main group they corresponded to moderate anxiety (Table 2).

According to the clinical questionnaire for the detection and evaluation of neurotic states by K. K. Yakhin and D. M. Mendelevich young people with periodontal disease had significantly lower scores on the scale of neurotic depression (ND) – 3.5 times lower than in the control group (p=0,0137). A similar situation was observed in the case of the analysis of hysterical type of response (HTR) values. Representatives of the main group had 7.9 times lower results on this scale compared with periodontally healthy subjects (p=0.0172) (Table 2).

There was a significant difference between the parameters of assessment of higher nervous activity in the main and control groups. Accord-

Table 2

The psychological characteristics in study groups (points)

Parameter	Main group (n=84)		Control group (n=72)		p
	M	m	M	m	
Well-being	5,13	0,14	5,42	0,14	0,1638
Activity	4,45	0,10	4,93	0,14	*0,0003
Mood	5,45	0,13	5,77	0,14	0,1300
TA	46,11	1,42	40,52	1,13	*0,0042
SA	42,84	1,41	38,69	1,10	0,0656
ND	0,64	0,50	2,22	0,50	*0,0349
HTR	0,26	0,48	2,05	0,53	*0,0172

Note:
* – significant difference between the values of the main and control groups

Table 3

Features of sensorimotor response and autonomic regulation in research groups

Parameter	Main group (n=84)		Control group (n=72)		p
	M	m	M	m	
SVMR	288,91	11,52	318,10	14,40	0,0890
MMR0	262,16	8,76	264,18	11,55	0,8432
CR13	347,98	6,13	353,79	6,98	0,5395
MMR 1	255,27	8,07	254,21	11,01	0,4847
Mcop1	63,53	9,93	37,67	13,14	0,1247
CR23	424,89	6,69	446,17	7,85	*0,0413
MMR 2	247,57	6,56	250,38	9,54	0,7593
Mcop2	135,49	11,31	122,40	15,61	0,6431
TP	4369,30	387,46	6805,22	842,77	0,0508
LFn	52,40	2,23	40,20	1,82	*0,0001
HFn	47,60	2,23	59,80	1,82	*0,0001
LF/HF	1,66	0,20	0,78	0,07	*0,0002
SI	91,99	11,16	58,07	6,22	*0,0101

Note:
* – significant difference between the values of the main and control groups

ing to the values of the choice reaction of two of the three signals (CR23) in young people with periodontal disease, 4.77 % lower values were registered compared to those examined in the control group (p=0.0413). There were no statistically significant differences in the average duration of the motor response (MMR2) and the average time of central information processing (Mcop2) (p=0.7593 and p=0.6431, respectively). Such data may indicate that the decrease in the latent period duration is due to an increase in the transmission speed through nerve fibers and synapses. In people with periodontal disease, there was also a tendency to reduce in value of latent periods of the simple visual-motor reaction (SVMR) compared with periodontally healthy subjects (p=0.0890) in the ab-

sence of difference in the average duration of the motor reaction (Table 3). This confirms the assumption of faster transmission of nerve impulses in the main group, because the time of a simple sensorimotor response includes excitation in different parts of the reflex arc, ie time for physicochemical processes in receptors that perceive stimuli, conduction of excitation to the CNS and then to the muscles [19].

According to the spectral analysis of heart rate variability, there was a tendency to reduce in total power of the spectrum (TP) in young people with periodontal disease by 1.6 times compared with those without this pathology. This parameter characterizes the state of regulatory mechanisms in general

and reflects the effect on the sinus node of both the sympathetic and parasympathetic parts of the autonomic nervous system [21]. However, the statistical significance of such differences was not confirmed ($p=0.0508$). The analysis of low-frequency and high-frequency oscillations power in normalized units (LFn and HFn, respectively) revealed a significant difference between the study groups. In particular, in the examined with periodontal tissues diseases, LFn values were 1.3 times higher than the results of the control group ($p=0.0001$), indicating an increase in the sympathetic regulation circuit activity. Accordingly, HFn values in the main group were 1.3 times lower than in representatives without periodontal pathology, which was confirmed statistically ($p=0.0001$). It follows that the representatives of the main group significantly reduced the impact of the parasympathetic part in the regulation of heart rhythm. These data are supported by the determination of the sympathetic-vagal index (LF/HF). Subjects with periodontal disease had significantly higher LF/HF than in the control group ($p=0.0002$). Namely, in the main group we observed an increase in its values by 2.1 times compared with periodontally healthy people. Using cardiointervalography according to R. M. Baevsky, the stress index (SI) was calculated, which was 1.6 times higher in representatives with periodontal diseases than in the control group (Table 3), reflecting the growing centralization of heart rate control.

Depending on the results of the analysis of heart rate variability, the rhythmogram class was determined. The main group was dominated by

I and II classes of rhythmogram (46.58 % and 36.99 %, respectively). In 16.44 % of cases, III and IV classes were detected. At the same time, the I class rhythmograms were most often found (77.78%) in the control group. In 14.81 % of subjects II class was detected, and the least common was the III class (7.41 %). This difference was confirmed statistically using Pearson's criterion χ^2 ($p=0.0018$) (fig. 3).

Based on the above results, the optimal predictors were selected: from the survey data – brush stiffness; from dental examination – all hygienic indices, RI and gum biotype; from psychological parameters – level of activity, TA, ND, HTR. CR23 was not included in the list of predictors due to lower reliability. Integral indicators LF/HF, SI, as well as the rhythmogram class were chosen from the parameters of heart rate variability analysis.

Using the method of machine learning based on neural networks, prognostic models were built to solve the problem of classification for the presence of periodontal pathology. Two neural networks were selected: one (1) included indicators of dental history and examination, psychological testing, assessment of higher nervous activity and autonomic regulation, and the other (2) – only selected indicators with the highest prognostic capacity without taking into account heart rate variability. This decision was made in order to enable the use of the proposed algorithm with minimization of the need for additional devices and to simplify its application in practice. The presence of periodontal diseases was considered a positive result in the prognosis, and the absence was considered negative.

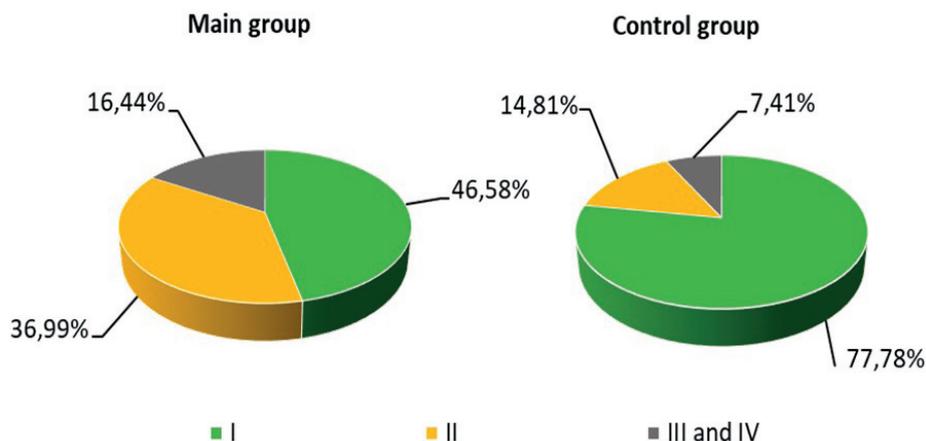


Figure 3. Distribution of rhythmogram classes in study groups

The first neural network contained one hidden layer and 10 neurons. The training sample included 65 % of cases, the validation sample – 15 %, and the test sample – 20 %. Data on this neural network are given in Table 4 (neural network 1). According to the results of prediction in the test sample, the number of false-negative results, i.e. cases of incorrect prognosis in subjects with periodontal disease, was only 16.67 %, and false-positive, i.e. cases of incorrect prognosis in subjects with periodontal disease – 7.69 %. Thus, the diagnostic sensitivity of the model was 83.33 % and the specificity was 92.31 %.

In addition, ROC-curves were constructed to evaluate the model (fig. 4). The area under the ROC-curve for the overall sample was 0.95, and for the test sample – 0.89, which indicates the high accuracy of the neural network.

To construct the second neural network, indicators of gingival biotype, GW, RI, activity, OT, ND and ITR were selected. This model contained one hidden layer and 6 neurons. The sample sizes were set in the same way as in the first model. The characteristics are given in Table 4 (neural network 2). Diagnostic sensitivity and

specificity in the test sample were 90.00% and 78.57%, respectively. The configuration and characteristics of the ROC-curve are slightly worse than in the first model (fig. 5). The area under the ROC-curve for the overall sample was 0.88, and for the test – 0.79, which indicates a significant efficiency of this neural network.

Thus, using these neural networks, it is possible to predict with high accuracy the development of periodontal pathology based on increasing estimates of hygienic indices, the presence of thin gingival biotype, decreased activity, increased trait anxiety and signs of neurotic depression or hysterical response, shifting the balance of autonomous regulation to the predominance of the sympathetic part and the general stress of adaptive mechanisms.

Discussion

Our work shows the relationship between psychophysiological features and the condition of periodontal tissues in young people. This connection is confirmed in our other works [22-24]. Scientific sources indicate the influence of psychophysiological features and periodontal status in children [25]. Some

Table 4

Characteristics of neural networks

№	Class	Accuracy, %		
		training sample	validation sample	test sample
1	Multilayer perceptron	91,57	88,89	88,00
2	Multilayer perceptron	87,80	83,33	83,33

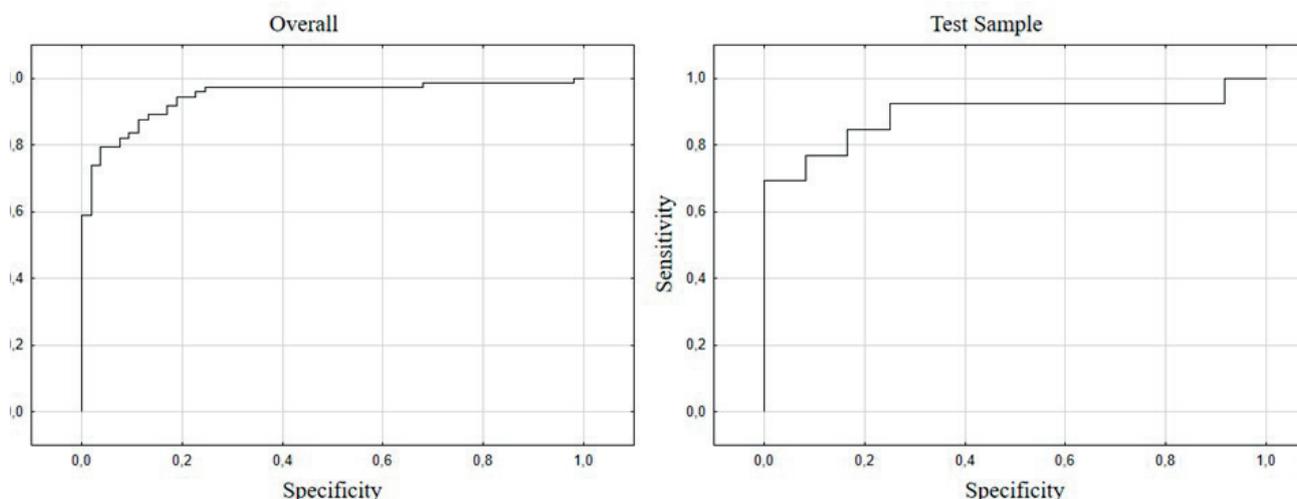


Figure 4. ROC-curve of first neural network for overall and test samples

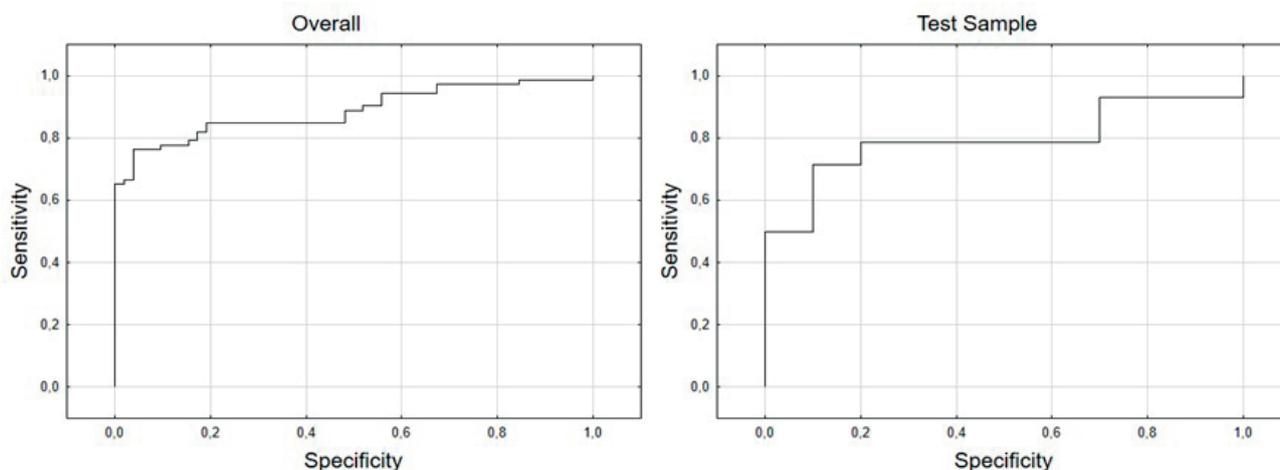


Figure 5 – ROC-curve of second neural network for overall and test samples

cover this issue for people of working age [26,27]. T. O. Petrushanko and co-authors investigated the possibility of using the J. Taylor scale in the prevention of periodontal disease [26,28].

The mechanisms that may explain the relationship between psychophysiological characteristics, infection and inflammation are well understood. Infection leads to the activation of the immune inflammatory response, which in turn stimulates specific areas of the brain. This triggers a regulatory mechanism that is closely related to stress systems and includes the hypothalamic-pituitary-adrenal (HPA) axis and the sympathetic nervous system [29]. In particular, glucocorticoids (such as cortisol), which are released in response to stimulation of the HPA axis, inhibit the activation of leukocytes, the production of pro-inflammatory cytokines and other mediators of inflammation. They also reduce the activity of Th-1 and stimulate apoptosis of eosinophils and some groups of T-lymphocytes [30]. The central and peripheral parts of the autonomic nervous system are also involved in the regulation of the inflammatory response through the neurotransmitters norepinephrine and acetylcholine and the hormone adrenaline [31]. Postganglionic endings of sympathetic nerve fibers also secrete peripheral (immune) corticotropin-releasing hormone (CRH), which has a proinflammatory effect in contrast to the central hypothalamic hormone [32]. In addition to autonomic innervation, immune system cells have pep-

tidergic links with sensitive fibers in the peripheral nervous system. For example, mast cells have receptors for substance P and CRH. Both mediators stimulate the degranulation and release of histamine, cytokines, leukotrienes, and other proinflammatory biologically active substances [30].

In addition, dysregulation of stress systems can cause microcirculatory changes and disorders. In particular, the activation of the sympathetic nervous system is accompanied by an increase in vascular tone and general vascular resistance, contributes to negative metabolic, trophic, hemodynamic and rheological changes in periodontal tissues [33].

Based on this, psychophysiological features can be effective predictors of the development of pathological processes in periodontal tissues, including inflammation. The complex noninvasive method of prediction used which includes both parameters of stomatological examination taking into account an index estimation, and indicators of psychophysiological parameters, provides high efficiency and accuracy in prediction.

Thus, the method of modeling using neural networks based on the index assessment of the condition of teeth hard tissues, the level of oral hygiene and the evaluation of psychophysiological features can effectively predict the risk of periodontal disease development in young people.

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