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# INFORMATION COMMUNICATION TECHNOLOGY FOR MONITORING OF THE PRENOSOLOGICAL STATE OF POPULATION HEALTH

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# INFORMATION COMMUNICATION TECHNOLOGY FOR MONITORING OF THE PRENOSOLOGICAL STATE OF POPULATION HEALTH

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## ABSTRACT

The article describes the development of an uninterrupted technology for the remote automated monitoring of the prenosological level of individual health, which allows optimization of the non-invasive medical examination of the population. To implement these examinations by using information and communication technologies, mobile communications, automated remote exchange methods, and the accumulation and storage of information involving medical knowledge, mathematical models and algorithms for their scientific analysis, opportunities are created for the development and implementation of preventive measures that serve as effective mechanisms to ensure a healthy lifestyle.

**Key words:** information and communication technologies in medicine, health monitoring, prenosology, health of healthy people, database.

## INTRODUCTION

Currently, modern medicine has at its disposal countless opportunities and technologies for the diagnosis and treatment of the most complex diseases. However, even with all these advances, modern medicine still mainly deals with already sick people who need medical attention. This means that sadly, instead of determining prognoses and preventing diseases, the current goals are concentrated on treating already unhealthy individuals. Thus, one of the crucial goals of health care, maintaining public health, cannot be fulfilled if it is mainly focused only on the treatment of diseases. This places prognosis at the heart of the health problem: the need to predict an individual's trajectory from fully healthy to ill. Future medicine should focus on maintaining the health of healthy people rather than on treatment. Currently, the term "health" is often interpreted as an absence of any disorders. The World Health Organization has defined health as a complex state of physical, mental and social well-being. Health science is a complex and multi-

layered study of not only physical health but also the environment in which we are living, which is saturated with both stressful and joyful situations that affect all individuals. The negative effects this may lead to are the so-called "the third state". The concept of the "third state" in assessing human health is actually based on the laws of ancient medicine, laid out more than a thousand years ago by the famous physician and philosopher Abu Ali Ibn Sina, also known as Avicenna, which highlight six human health conditions: a perfectly healthy body; a not-perfectly healthy body; a body that is not healthy but not sick either; a body that can easily perceive health; a body that is partially sick; and a body that is totally sick [1]. Of all these conditions, only the last two relate to illness. Between these two extreme levels of health (according to Avicenna), we distinguish four transition states with varying degrees of tension in regulatory systems: normal, moderate, pronounced and overstrained [2]. Consequently, the transition from a healthy state to disease occurs through overstrain and the breakdown of adaptation mechanisms. The sooner such an outcome is predicted, the more likely it is to maintain the well-being of the population. Health is considered a process of continuous adaptation of the body to environmental conditions, and one measure of health is the adaptive capability of the body. Hence, between health and illness, a whole series of marked transitional conditions, called prenosological conditions, occurs.

These points, together with the unresolved problems of the rational organization and management of the lifestyle of the majority of the population, are the basis for the massive occurrence of prenosological disorders and their inevitable transformation into various forms of pathology and form a part of the global problem with maintaining health. For instance, the results of mass preventive examinations showed that 50% to 80% of the population is at different stages of prenosological conditions [3]. Thus, most people do not need a medical diagnosis (disease diagnosis) but rather a prenosological diagnosis. The concept of the adaptive capability of an organism includes two aspects: diagnostic and prognostic. The first represents the current state of the body, the stock of its functional reserves and the corresponding strain of its regulatory systems. The second characterizes the potential ability of the body to perform a particular activity. Adaptation reserves, in general, represent the ability of the human body to resist the effects of various types of loads, adapt to these loads, and minimize their impact on the body, while ensuring the proper level of effective activity of cells, tissues, organs and the whole organism while providing the proper level of effective human activity. The body's adaptive reserves are essentially a criterion of physical health.

We can conditionally differentiate the following stages of the body [2, 3]:

- State of satisfactory adaptation;
- State of strained adaptation mechanisms (unstable or incomplete adaptation);
- State of unsatisfactory adaptation (overstrain of adaptation mechanisms);
- State of adaptation failure (depletion of adaptation mechanisms).

Recognition of these functional states reflects the outcomes of adaptive behaviour and is called prenosological diagnostics (PD), as this determines the conditions preceding the development of nosological forms of diseases. This is exactly what the prognostic aspect of prenosological diagnostics consists of, which recognizes the current functional state of the organism.

**The purpose and objectives of the research.** Currently, disease prevention is the most important public health priority and aims to create motivations for a healthy lifestyle (HLS) among the population, fortify physical and mental health and maintain the well-being of the population.

This assignment is undoubtedly of utmost important in health care reform, given that it has the most significant economic role associated with maintaining people's health, improving labour potential, and significantly reducing the population's need for medical care. The significance of prevention and a healthy lifestyle was postulated in the Government Decree of the Republic of Uzbekistan No. 718, released September 13, 2017. The Decree included the implementation of measures for the prevention of diseases, promotion of a healthy lifestyle and formation of a sanitary-hygienic culture among the population as the main direction of preventive medicine. The goal was to ensure the early detection of diseases by organizing high-quality preventive examinations that ensure the full implementation of preventive measures and to introduce their systematic monitoring as a priority task of the country's health care system. Therefore, the urgent task of the health care system of the Republic at present, along with increasing the efficiency of nosological diagnostic and treatment processes, i.e., the treatment of already sick people, is the organization of mass prenosological examinations to assess the level of the functional health state of the population, the introduction of a monitoring system for these examinations, the early identification of risk factors (RFs), and, if necessary, the implementation of preventive measures to correct them, ensuring the preservation of health. Taking into account the volume of information received and processed, as well as the unorganized nature of prenosological examinations of the population, in order to implement the above-mentioned solutions, it is necessary to develop special remote, mobile information and analytical communication technologies that automate the collection of primary personalized information and its storage, the analysis of monitoring and scientific data, the identification of risk factors and prediction of the health status of the population. It should be noted that the goal of health monitoring, based on data on the individual characteristics and capabilities of the body, is to ensure the preservation of health in the process of its individual development. In fact, this task is related to ensuring the health of the population. First, it requires PD of an individual's level of health and early identification of risk factors, assessment of the level of morphological and functional indicators of the body, identification of negative trends, and, if necessary, without waiting for the manifestation of the disease, timely implementation of effective targeted and individual preventive measures. Prenosological changes in body parameters are the earliest and most common; they reflect the cumulative effect of various adverse factors on human

health and therefore should be monitored first. The problem of assessing the prenosological level of health is primarily associated with the development of effective and highly informative methods for its diagnosis [2-4]. Conventional diagnostic technologies in clinical medicine determine the state of health in terms of the existence or absence of any pathological changes. The prenosological state does not exceed the limits of the clinical norm. At the level of laboratory and instrument-based investigations, the prenosological state does not show significant changes in the generally accepted norm; therefore, it falls outside of the field of view of doctors. PD considers reducing the adaptive capacity of the body as a leading cause of the onset and development of diseases. Its primary task is to scientifically determine the extent of a person's possible adaptations and the development of his or her disease. The next task to address is the determination of preventive measures necessary to improve adaptation and health. The most important goal of preventive medicine is the search for direct tools for prenosological diagnosis and their disclosure as innovations in the provision of services in the social sphere and the examination of practically healthy individuals to detect RFs, latent and unrecognized cases of diseases. Thus, preventative medicine allows the early detection of developing diseases before clinical symptoms are detected, ultimately allowing the level of health of the population to increase, which is one of the priority areas of modern medicine. In this aspect, the development and implementation of new approaches and methods that could improve the quality, reliability, mass character and targeting of prenosological diagnostics is especially relevant.

**Materials and Methods.** A prenosological examination focuses on determining the level of vitally important functional capabilities of the person's cardio-respiratory, muscular, central and autonomous nervous systems, coordination-motor and morphological characteristics and regulatory mechanisms [5-8]. This information is important for determining predictors of the development of pathological conditions, identifying risk factors, and assessing the effectiveness of individual rehabilitation programmes. Based on these data, and considering the individual characteristics of each person, targeted preventive measures and programmes can be developed for implementation, ensuring the correction and identification of prenosological disorders and the prevention of the development of chronic non-infectious diseases that are relevant for maintaining healthy health.

Thus, in contrast to classical medicine in clinical and outpatient facilities, the objects of prenosological diagnostics are usually healthy people. Their interest in this type of examination is determined by the form and content of their conclusions and also depends on their comfort with the applied diagnostic and correction technologies.

A comprehensive assessment of the level of the prenosological functioning states of the body and indicators of its health and the application of modern information technologies allows us to create a data bank of health conditions, conduct long-term automated monitoring of changes in the health of the population, and implement ways to correct population health, directed to the

optimal and wide-ranging physiological and socio-psychological adaptation of the individual. This assessment should also consider the impact of exogenous and endogenous effects on health and the effectiveness of ongoing health and corrective measures. When we talk about the remedies of health correction and disease prevention, it should be noted that this entire complex is used at the preclinical stage and is designed for the mass consumer who does not have medical knowledge. Accordingly, we can only talk about means of non-pharmacological correction of health (healthy lifestyle, balanced diet, physical activity, personal hygiene, psychocorrection of communication, etc.). PD helps in the development of systems of dynamic control over the health status of adults, even at home, without having to visit a medical institution.

There are two PD methods:

- Prenosological screening: the selection of people with certain functional conditions for the subsequent resolution of issues of their recovery;
- Prenosological control: dynamic monitoring of the functional state of healthy people.

Monitoring the health of individuals, that is, prenosological control, is a practical step towards dynamically assessing the state of the individuals' regulatory systems, identifying the very initial manifestations of their overstrain—both in the whole organism and in individual organs and systems—and correcting them in a timely manner. The volume of work, if the entire population is covered, will be tens of times that currently undertaken in the health care system, where work is done only with already ill parts of the population. Therefore, the implementation of health monitoring by conventional methods, using the capabilities available in the current health care system, is difficult and sometimes even impossible. The process of prenosological research in all cases is a recognition process using both simple logical rules and complex mathematical techniques. However, it always stands out due to its non-invasiveness, comfort and short time for diagnosis. It is worth mentioning another important methodological principle of prenosological diagnosis, the use of information-intensive research methods. This means that with minimal examination time and methodological simplicity, extensive and valuable information must be obtained that allows important conclusions to be drawn about the state of the regulatory mechanisms, functional reserves and level of functioning of the main vital systems of the individual. This principle is fundamental in the elaboration of specific technologies, the development of the algorithm for its implementation and the establishment of the rules and knowledge used in this process. In this regard, to tackle these problems, it is necessary to attract the modern capabilities of information and communication technologies, mobile communications, automated remote exchange methods, and accumulation and storage of information, as well as mathematical methods and algorithms for their scientific analysis. As a result of their application in the practice of mass population surveys, it becomes possible to develop and implement preventive measures that serve as effective mechanisms for ensuring the preservation of health.

A number of systems and mobile applications have been developed for monitoring and tracking health [11-13]. The issues regarding the need to create and implement remote monitoring of human health indicators as a means of improving the quality of medical care for patients and the main features of creating a specialized automated system for these purposes are considered in [14].
Information technologies [11] lead to new possibilities in early and individualized prenosological diagnostics, serving as a useful tool for accurate and standardized assessments of the effects of external adverse factors on human health and general physical condition. Reference [12] presents the conceptual foundations and architecture of an Internet-based system of personalized health care based on intensive data analysis and describes the structure of the health management space and the general architecture of the Internet-based system of personalized health care support. In this regard, the works from Tomsk State University, describing an information system for monitoring the adaptive abilities and functional reserves of an individual, also deserve attention [13].

**Results.** Through the technology we developed, we can use algorithms and software for remote, automated monitoring of the prenosological level of an individual's health. This will allow us to optimize dispensary examinations for the population, ensuring that they provide necessary coverage, are low cost, operate continuously and, when using modern algorithms for recognizing specified signs, are intelligent. A condition needed for the implementation of the project is the assignment of the role of the correspondent, at least one in each family, who will oversee transmission and receipt of personal electronic medical data for the population itself. At the same time, to minimize financial costs for the purchase of foreign medical devices, it is necessary to train the population to receive data on the morphological and functional indicators of the body using non-invasive and generally accessible methods and send them to the appropriate health centre serving its territorial unit using a personal mobile phone. The hardware and software provisions of each such module require the presence of at least one mobile communications device in each family with the necessary parameters and a connection to the Internet. For all families, such mobile communications devices will be equipped with the correct software and interfaces for exchanging information with the server of their corresponding health centre. This will make it possible to connect a mobile patient with a virtual doctor. By establishing individual monitoring of the prenosological level of health based on this principle and organizing its modular functioning for a specific portion of the population of a given geographical area with the involvement of prevention doctors responsible for this part of the family clinic, significant results can be achieved in preventing risk factors and maintaining the health of the population. As a module, we have taken the conventional eastern public structure of citizens' self-government, the "mahalla", an association of citizens created in their place of residence and functioning in accordance with the special law of the Republic of Uzbekistan. As a pilot project we are implementing the described modular principle and mechanism for remote monitoring of the prenosological level of individual health among the

students of the Ferghana branch of the Tashkent Medical Academy as a structural unit. The architecture and diagram of the information and analytical remote technology we developed are presented in Fig. 1. In the initial version of the project, using the effective non-invasive methods for assessing the level of health described in the literature [5-10], we envisage implementation based on individual student indicators, medical knowledge bases (formed from the literature data on quantitative and qualitative criteria for evaluating certain indicators of the level of body health), and remote individual assessments of the adaptive potential and functional reserves of the body (specifically, the state of the autonomic regulation of the cardiovascular system as a prediction of the possibility of developing arterial hypertension), as well as a number of anthropometric and morphofunctional indices, allowing us to evaluate the prenosological level of the students' somatic health.

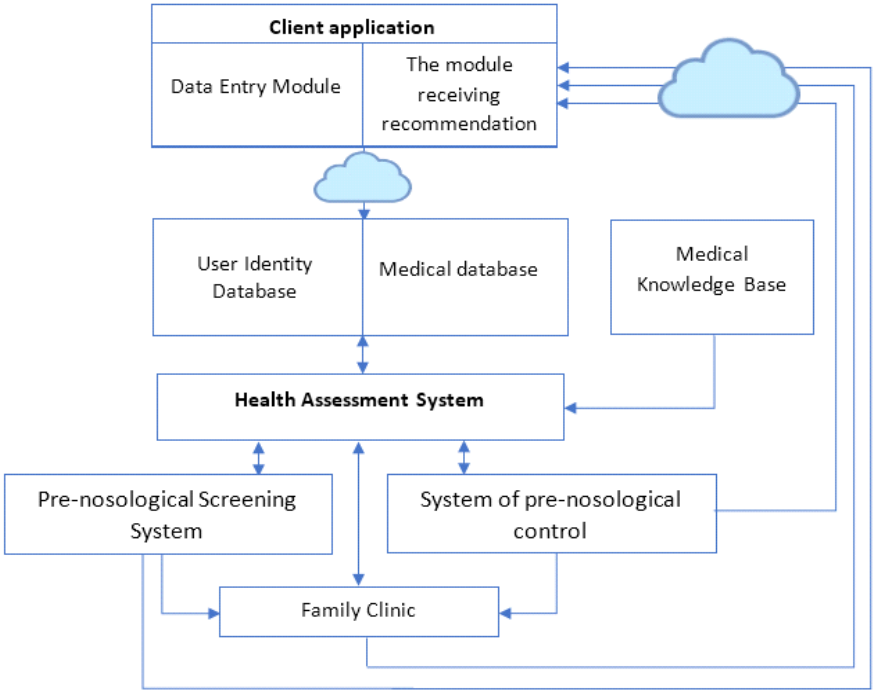


**Figure 1. Structural scheme of the system**

The subsequent assessment of physical status was obtained by the general method of somatometry by calculating the average value of the Ketle index (IR). An increased Ketle index is considered one of the risk factors for arterial hypertension. Based on anthropometric data, the Piñe indices were calculated, according to which the somatotypes of the examined students were determined.

The simplified algorithm of prenosological diagnosis describes well the functional states where a stable relationship between the main physiological parameters is preserved. According to the study of the functional status, the value of the indicators of physiological reserves of the respiratory system (from the Stange and Gencha tests) was obtained. The data obtained reflect the power levels and the efficiency of aerobic energy production. To determine the resistance to hypoxia, the ratio of the resting heart rate to the duration of inspiration apnoea was calculated. An informative and integral prenosological indicators reflecting the

features of the adaptive-adaptive reactions of the body in a healthy population is the type of self-regulation of blood circulation (TSC). Based on an integrated assessment of the cardiovascular system and an analysis of the ratio of the cardiac and vascular components of central haemodynamics, N.I. Arinchin et al. established the existence of three types of TSCs in healthy people: cardiac, vascular, and cardiovascular [9]. Determination of the TSC type makes it possible to assess the level of tension in the regulation of the cardiovascular system. It is worth mentioning that the prospect of the transition of the prenosological state into the disease state is determined by the adaptive capability of the body and, in particular, the regulation of physiological functions. Therefore, an important position in promising medical control systems should be taken by information technologies aimed at assessing the state of the regulatory systems since, as already mentioned, it is the overstrain of regulatory mechanisms as well as the associated decrease in functional reserves that serves as one of the main risk factors for the development of disease [6]. The cardiovascular system, as a sensitive indicator of adaptive reaction of the whole organism, is the first to respond to all fluctuations in environmental conditions; it is a regulator of the internal body environment, maintaining homeostasis of its organs and systems through their adequate blood supply. In this regard, as a criterion of the adaptive capabilities of the organism, R. M. Baevsky and A. P. Bersenev proposed to determine the index of functional changes (IFCh) [2] via the formula IFCh = 0.011HSS + 0.014SAP + 0.008DAP + 0.014A + 0.009BW-0.009H-0.27, calculated using only the heart rate (bpm/HR), diastolic and systolic arterial pressure (DAP, SAP), height (H), body weight (BW) and age (A), which can be obtained by non-invasive methods. Based on the obtained IFCh value, each individual, depending on the degree of adaptation, can be assigned to one of four groups (satisfactory adaptation, strained adaptation mechanisms, unsatisfactory adaptation, failure of adaptation): the higher the conditional value of the IFCh, the higher the likelihood of pathological deviations. Pre-medical screening, based on the evaluation of the IFCh, with all its simplicity, provides a systematic approach to assessing the functional state of the circulatory system as an indicator of the adaptive capabilities of the body as a whole. The level of functional reserves, which we monitor according to the Kournikova approach, is an independent prenosological indicator of health, adequately reflecting the state of the body's adaptation systems to adverse environmental influences [7]. Moreover, it is the most sensitive and dynamic criterion that allows the identification of priority risk factors.

We should note that the examination protocol is dependent on the purpose of the prenosological examination and may vary depending on the tasks and the volume of the studies. The software for evaluating the analysis results and forming conclusions is the most important and crucial part of the technology of prenosological studies. The issues of constructing algorithms for recognizing various classes of prenosological conditions are fundamental in solving the problems of automating the mass prenosological diagnostics associated with the examination of large populations. Here, the selection of the most informative

indicators is necessary as is their minimization with the development of optimal decision rules. The algorithm, as the exact instruction of the execution order for a certain group of actions or operations, may lead to the solution of the task, but it should be construct on scientifically based criteria. In this case, in terms of the algorithms for prenosological diagnostics, we refer to the physiological criteria that we have accumulated in the knowledge base of the analytical unit of our system. At the same time, we have accounted for the fact that various physiological indicators used in assessing the functional state have different information content and accordingly make unequal contributions to obtaining the final result in the formulation of the prenosological diagnosis. Indicators that assess the level of human health at the individual level, even if informative, do not give a holistic view. The integration of separate parameters is necessary to obtain a total quantitative indicator (index) of health. This is a reason for introducing the idea of the prenosological syndrome as an indicator of the complex of certain deviations of different indicators. To assess the integral level of health, we used the Apanasenko method, where a similar approach was implemented using 5 indicators of the body [15]. The listed factors, adequately characterizing the level of the prenosological state of the body, are calculated based on data determined with non-invasive methods, which are important for the prenosological monitoring of the health of individuals. Algorithms for the factor analysis of recorded indicators, including morphofunctional development, functional reserves and the conditions of leading organs and systems, provide a clear relationship between morphofunctional development indicators and health status and the determination of the individual's internal health structure. This function is performed by using the algorithm we developed and the software for automated computer implementation, which allows us to assign each object of investigation and those from the corresponding population databases to one of the following categories:

Category 1: People with a high level of health who do not require the implementation of any preventive measures - the contingent of the green folder base;

Category 2: People with risk factors for health - the contingent of the yellow folder base;

Category 3: People with one or more chronic diseases - the contingent of the red folder base.

We should note that to identify each monitoring object in the database and in all information registers, it will be assigned a unique, individual 15-digit number by which the correspondent can set its address and status in the family and, if necessary, convert it to information according to its passport data. Thus, according to the goal, comprehensive monitoring of the physical, functional and clinical-somatic status of population health indicators is achieved. This system provides for the implementation of the functions of prenosological diagnosis, screening and control, namely:

Comprehensive prenosological examination of citizens, including anthropometric and other morphological and functional indicators, including

screening, assessment of the level of somatic health and of the functional and adaptive reserves of the body, rapid assessment of cardiovascular and autonomic systems, and assessment of complex indicators of the function of the respiratory system. Based on the results of the surveys, an assessment can be conducted to determine the level of risk of onset of certain diseases.

Participation or assistance in the implementation of measures to create a healthy lifestyle and reduce the spread of RF of noncommunicable diseases of the environment of the population, carried out by the territorial centre for medical prevention and other organizations, as well as dynamic monitoring of the contingent of people at increased risk of developing non-infectious diseases and referring them to internist doctors. The ability to apply this technology in practice would allow us to conduct mass prenosological examinations of the population and improve their health and the quality of targeted, personalized prevention of risk factors.

**Authorship.** Author Karabaev M.K. contributed the analysis of the literature on this topic and the relevance of the development and implementation of new approaches and methods that could improve the quality, reliability and targeting of prenosological diagnosis. He outlined the main areas of organization of mass prenosological examinations to assess the level of the functional state of the body of the population and introduced the systematic monitoring of these examinations, the early identification of risk factors and the implementation of preventive measures to correct them, ensuring the preservation of the health of healthy individuals.

Author Abdumanonov A.A. contributed to the creation of the algorithms, the structure of the database and computer program, the collection and analysis of data, the storage of information, as well as the involvement of medical knowledge, mathematical models and algorithms for their intellectual analysis of the data from a specific contingent of the population to provide remote automated monitoring of the prenosological level of health in this research.

**Conflicts of interest.** The authors confirm that this article content has no conflicts of interest. The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

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