METHODOLOGICAL ASPECTS OF RISK MONITORING FOR THE HUMAN HEALTH SHAPING, MAINTENANCE, AND PRESERVATION DIGITAL PLATFORM

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Solving the problems of ensuring long and active life of all Russians, regardless of their place of residence, requires the development and implementation of digital preventive medicine technologies. It is noted that it is necessary to develop and implement health risk monitoring consistent with the digital technology development level, principle of data-driven management, and conceptual provisions of the disease prediction and prevention, personalized and participatory nature of medical care to create the human health shaping, maintenance, and preservation digital platform. The paper provides the rationale for the fact that the block (cascade) diagram of occupational health changes in aviation, the use of which as part of the digital platform to be created requires enlargement of the set of blocks of the health risk minimization cascade and the cascade of the risk factor effect minimization aimed to consider all the health risk minimization potentialities, as well as to develop methodological support of the risk factor dose and health risk calculation aimed to cover the maximum number of social and occupational population groups, meets these requirements.

Keywords: cascade diagram of health changes, digital preventive medicine, health risk, health risk monitoring, digitalization of healthcare, data-driven management, 4P-medicine, health risk management

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МЕТОДИЧЕСКИЕ АСПЕКТЫ МОНИТОРИНГА РИСКОВ ДЛЯ ЦИФРОВОЙ ПЛАТФОРМЫ ФОРМИРОВАНИЯ, ПОДДЕРЖАНИЯ И СОХРАНЕНИЯ ЗДОРОВЬЯ ЧЕЛОВЕКА

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Решение задач обеспечения продолжительной и активной жизни всех россиян, вне зависимости от их места проживания, требует разработки и реализации технологий цифровой профилактической медицины. Отмечено, что для создания цифровой платформы формирования, поддержания и сохранения здоровья человека необходимо разработать и реализовать мониторинг рисков здоровью, соответствующий уровню развития цифровых технологий, принципу управления на основе данных и концептуальным положениям предупреждения и предотвращения заболеваний, персонализации и партисипативности медицинской помощи. В статье приведено обоснование того, что этим требованиям соответствует структурная (каскадная) схема изменений профессионального здоровья в авиации, применение которой в составе создаваемой цифровой платформы требует расширения набора блоков каскада минимизации рисков здоровью и каскада минимизации эффектов факторов риска в интересах учета всех потенциальных возможностей минимизации рисков здоровью, а также развития методического обеспечения расчета доз факторов риска и рисков здоровью в интересах охвата максимального количества социо-профессиональных групп населения.

Ключевые слова: каскадная схема изменения здоровья, цифровая профилактическая медицина, риск здоровью, мониторинг рисков здоровью, цифровизация здравоохранения, управление на основе данных, 4П-медицина, управление рисками здоровью

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One of the national development goals of the Russian Federation for the period until 2030 and for the future until 2036 is determined as “maintenance of the population, health improvement, human well-being promotion, support of the family”, and achieving these goals envisages “creation and launch by the year 2030 of the digital platform contributing to shaping, maintenance, and preservation of human health throughout human life based on the data-driven management principle” [1].

The key objective of the digital platform created is to ensure reliable intuitive digital service for the citizens’ communication with medical professionals and medical institutions, access to the digital health profile, features regarding self-monitoring and decision-making to maintain and improve health.

The experience in the development and operation of the digital services that are comparable in scale (public services portal, banking applications, etc.) suggests public confidence in reliability and confidentiality of the information acquisition and processing. That is why the issues of implementation of the consolidation of personal data (including health information) of the patients from medical institutions of various ownership and independently acquired information at the federal level within the framework of the digital platform developed are potentially

solvable. However, it is still necessary to earn the citizens' trust in terms of usefulness of the digital platform created for health maintenance and improvement.

Consolidation of information about the citizens' health provides a framework to address the issues of preventive medicine: prevention of diseases and injuries, prevention and elimination of the risk of diseases and injuries. Objective information about health risks is needed to solve such problems [2–5]. The analysis of past experiences shows that the issues of health risk monitoring are effectively resolved using the block (cascade) diagram of occupational health changes in aviation [6].

The study was aimed to provide the rationale for proposals regarding adoption of the block (cascade) diagram of occupational health changes in aviation for solving problems of risk monitoring during implementation of the digital platform for human health shaping, maintenance, and preservation.

Methods

We performed systematic analysis of the block (cascade) diagram of occupational health changes in aviation in order to determine the possibility to ensure it keeps pace with the digital technology development and is consistent with the data-driven management principle and the concept of 4P-medicine based on the principles of predictive, preventive, personalized, and participatory healthcare.

Block (cascade) diagram of health changes

During their life humans are continuously exposed to the effects of manageable (behavioral, metabolic, environmental) and non-manageable (biological, genetic, demographic) health risk factors. The impact of risk factors on human health is largely determined by the person's individual characteristics combining the following: body's compensatory response specifics; prior condition; individual resistance to the effects of certain risk factors; mobilization of body reserves; psycho-emotional, motivational, and volitional commitment to activity, etc. [7–9].

The changes in human condition resulting from the current and cumulative effects of adverse factors lead to depletion of body's reserve capacity and, as a consequence, to deterioration of health [10–12]. Reduction of the effective dose of the exposure to factors requires an integrated solution to multidirectional super-tasks:

– human health preservation and professional longevity extension require reduction of the dose and intensity of the influencing risk factors;

– the need for life support in the context of increasing industrial and domestic equipment capacity, increasing intensity of professionally significant information flows, reduced time costs for the decision-making support in the course of activity requires life support in the context of increasing health risk factor intensity and exposure time [13, 14].

A complete picture of immediate (acute) and delayed effects of such changes is described by the cascade diagram of health changes (Fig.) based on the dose approach to standardization of factors [6]. The operation logic of such diagram combining blocks that belong to one of three cascades is as follows [6]:

– the risk of potentially dangerous conditions and health deterioration is determined by the risk factor dose in accordance with the first cascade;

– reduction of the dose of the risk factors of adverse conditions and health deterioration is achieved through blocks of the second and third cascades.

Lines on the diagram show the relationships between the cascade blocks (Fig.); different line patterns are chosen only for reasons of better readability of the drawing.

There is a factor dosimeter in front of each block (designated by double lines in the Figure) — a module (block, device) calculating the actual dose of the risk factors (D_i) determining health risk (R_i) for each i^{th} block of the cascade. Thus, in terms of digital technology, we can say that each i^{th} block of the central cascade ensures conversion of the risk factor dose arriving at the input to the health risk estimate R_i:

$$R_i = f_i(D_i),$$

where f_i is a functional relationship between the risk factor dose and the health risk. Construction (structural and parametric identification) of the functional dependence f_i for specific risk factors, specific health problems, and specific social and occupational population groups is a challenging problem requiring the joint effort of physicians and engineers (mathematicians). However, it is necessary to ensure the methodological approach "transparency" providing confidence in the risk estimates obtained. This, in particular, eliminates the possibility of using neural network technologies for calculation of health risk estimates. The methods and examples of effective solution of the problems of synthesis of the functional dependencies linking the risk factor dose and the health risk estimates are presented, in particular, in the papers [15–21].

The risk factor doses arriving at the factor dosimeter input are essentially exposure doses, while the doses at the factor dosimeter output are absorbed (effective) doses. Apparently, the following relationship is true for the risk factor doses:

$$D_1 \geq D_2 \geq D_3 \geq D_4 \geq D_5 \geq D_6 \geq D_7,$$

moreover, the equal sign is possible only in the case of ineffective functioning of all the blocks linked to the appropriate factor dosimeter.

A similar relationship is true for health risk:

$$R_1 \geq R_2 \geq R_3 \geq R_4 \geq R_5 \geq R_6 \geq R_7,$$

moreover, the equal sign is possible only in the case of ineffective functioning of the appropriate cascade block.

The theoretically possible situations, where the cascade block leads not to the decrease, but to the increase in the doses of factors and health risks, are not considered; the axiom about the good faith of the developers of the measures specified in the relevant blocks is accepted.

Three interrelated, continuously interacting cascades that constitute the cascade diagram of health changes (Fig.) are united by the blocks solving specific problems [6].

The first (cental, core) cascade is a *cascade of health changes*, around which a system counteracting the negative influence of risk factors on health and minimizing the effects of such influence is formed. It describes the sequence of health risk formation and manifestation and includes the links of the influences considered, each of which corresponds to the block of this cascade. Specialists from many branches of science are engaged in the multifaceted study of the first cascade blocks, and the progress of such studies is considered to be associated with taking into account the increasing number of the cascade blocks characterizing various aspects and components of human health. In the Figure, the first cascade includes six sequentially linked blocks.

1. Human body under specific conditions of vital activity: determines health risk (R1) based on the individual characteristics of the body, exposure and dose of the influencing health risk factors.

2. Immediate (acute and early) manifestations of health deterioration: determines the health risk (R2) manifesting itself within a month from the date of the risk factor exposure termination.

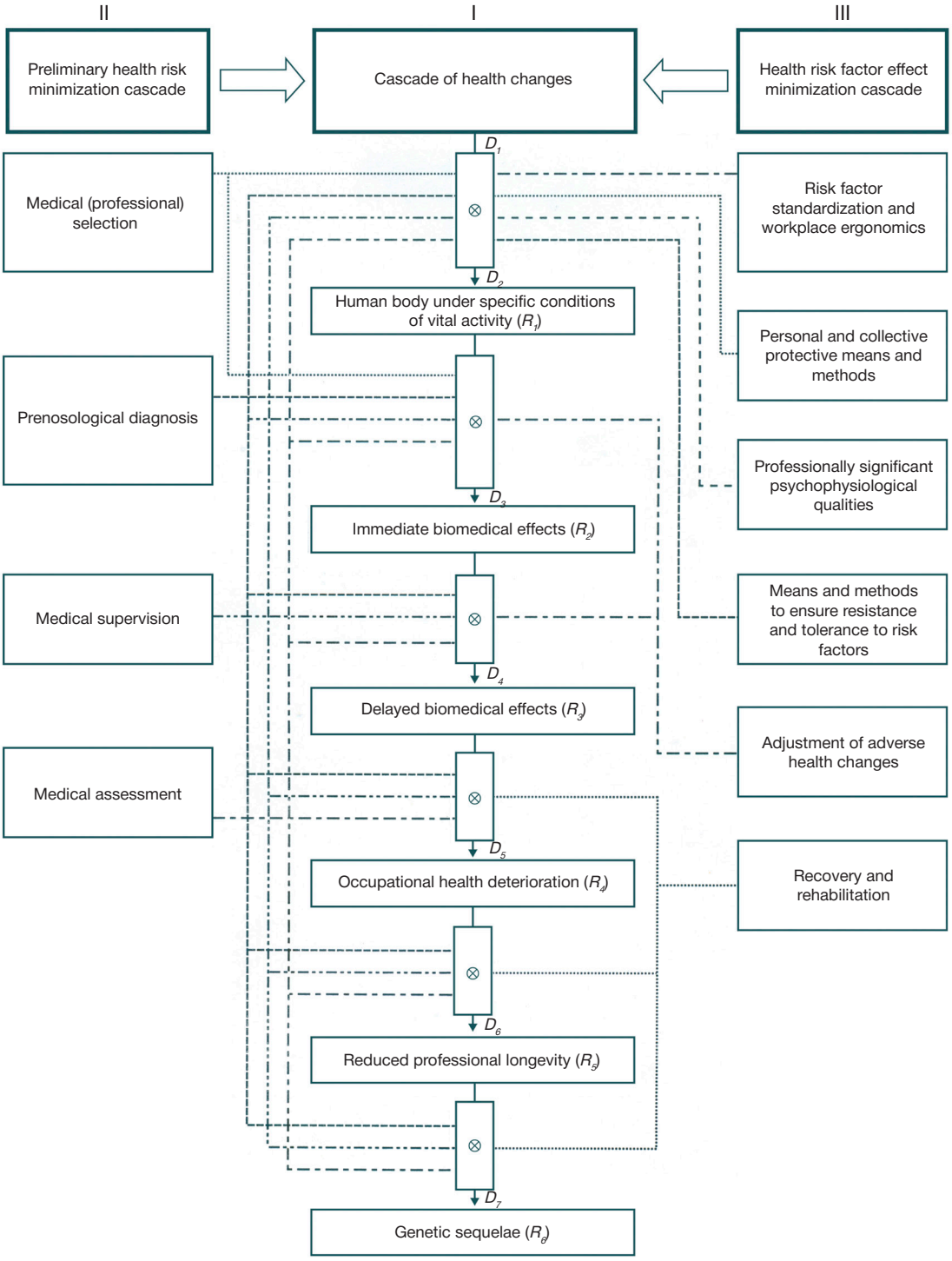

Fig. Block (cascade) diagram of health changes

3. Delayed manifestations of health deterioration: determines the health risk (R_3) manifesting itself within a period exceeding a month from the date of the risk factor exposure termination, as well as the risk resulting from the cumulative effect of such factors.

4. Occupational health deterioration: determines the health risk (R_4) characterized by the body's inability to maintain the compensatory and protective properties that ensure working capacity and human endeavor reliability under all conditions of professional activity implementation.

5. Reduced professional longevity: determines the health risk (R_5) characterized by the individual's inability to maintain professional working capacity, i.e. inability to execute professional tasks at the desired level (with the desired quality) throughout the period of employment determined by society.

6. Genetic sequelae: determines the health risk (R_6) causing abnormal changes in the body that are transmitted to the next generation.

The second *cascade is a cascade of a priori measures* aimed to minimize the risk of adverse health changes. It combines medical and professional selection, prediction of human body resistance (including phenotyping), prenosological diagnosis, medical supervision, and medical assessment. In the Figure, the second cascade includes four independent blocks.

1. Medical (professional) selection: system of measures aimed to minimize the risk that an individual would be engaged

in the labor activities inconsistent with his/her health status and physical development level.

2. Prenosological diagnosis: system of measures aimed to minimize the risk of failure to reveal adverse changes in the body not registered as a diagnosis (prenosological dysfunction of the body).

3. Medical supervision: system of measures aimed to minimize health risk through continuous health monitoring, compliance with the sanitary, hygienic, and epidemiological standards and rules.

4. Medical assessment: system of measures aimed to minimize the risk that the citizens unable to perform activities due to their current health status would be allowed to perform such activities.

The third cascade is a *cascade for prevention of the developing health problems*. It characterizes a multi-level structure of biomedical and psychophysiological "restraints" to the effects of risk factors. In the Figure, the third cascade includes six independent blocks.

1. Risk factor standardization and workplace ergonomics improvement: system of measures aimed to minimize the health risk resulting from the fact that the risk factors exceed the acceptable (permissible) levels and from uncomfortable task execution conditions.

2. Personal and collective protective means: means for prevention or reduction of the effects of harmful and hazardous occupational factors, as well as for protection against the polluted environment.

3. Development of professionally significant psychophysiological qualities: system of measures aimed to minimize the health risk resulting from the individual's inability to self-regulate his/her psychophysiological state when performing the activity.

4. Increasing resistance and tolerance to risk factors: system of measures aimed to minimize the health risk resulting from the exposure to the risk factors that are above the permitted standards.

5. Adjustment of adverse health changes: system of measures aimed to minimize the health risk resulting from the development of problems detected at the early stage and not requiring dismissal of an employee from the activities for health reasons.

6. Recovery and rehabilitation: system of measures aimed to minimize the health risk resulting from the reduced human body's functional capabilities.

It is clear that the more blocks of the second and third cascades are connected to the first cascade, the less likely and severe are adverse health changes resulting from the risk factor exposure (the less are appropriate D_i and R_i values). That is why one of the priority directions of health risk management is the development of means and methods to determine the contribution of each block of the second and third cascades to health riskometry in the units of the decrease in the effective dose of each risk factor or the decrease in the risk of adverse effects of the exposure to each risk factor according to the "cost–benefit" criterion.

The cascade diagram is of fundamental nature and is in principle applicable for health monitoring in representatives of any social and professional population group. However, to date, it has been largely adapted for health monitoring in pilots and astronauts [15, 18, 20, 22]. The main reason is the centralized, systematic and continuous nature of medical care provided to pilots and astronauts.

Currently, thanks to healthcare digitalization, the centralized and systematic medical care is provided to representatives of all social and professional population groups, which opens up new scopes of the cascade diagram application [23–28].

Data-driven management of health

It should be emphasized that the produced digital platform for human health shaping, maintenance, and preservation throughout the life will be constructed in accordance with the data-driven management (DDM) principles, which will contribute to the effective practical use of the cascade diagram in digital healthcare.

The digital platform implementation in accordance with the data-driven management principles implies that information about human health is used not only for one-time or periodic support of making decisions about human health shaping, preservation, and restoration, but also for continuous support of such decision-making throughout human life (including perinatal period). The solution to such problems is achieved through implementation of business processes (sets of interrelated tasks and activities aimed at achieving certain goals or results within the framework of the digital platform) on the demand of users (on-demand) for data streaming resulting from the network communication of the digital platform participants aimed at performing certain actions precisely in those moments when it is necessary (realization of the "on-demand economy" concept) [29].

The data-driven management of human health shaping, preservation, and restoration is a cyclic process: health information from multiple sources is continuously collected on the servers; the information collected is processed and analyzed automatically, the results are provided to users online in accordance with the information access policy. The management efficiency largely depends on the organization of data handling that involves ensuring data acquisition, data storage, data analysis (processing), data exchange, communication between the process participants, and many other things. Furthermore, it is necessary to ensure [30]:

– consistency: all the information acquisition and handling processes, software applications and data repositories should constitute a single, continuously functioning system with the universal architecture;

– agility: the management processes should be realized based on the agile technology ensuring quick response to changes in the "external environment", quick adaptation of services to user needs, continuous monitoring of the internal processes underlying the digital platform functioning aimed at ensuring continuous optimization of the processes;

– transparency: ensuring the possibility of tracking information at any time using the big data technologies and the distributed ledger technologies (blockchain technologies), continuous monitoring of costs and resources making the results accessible for all users in accordance with the policy of restricting access to information;

– parsimony: the digital platform single information space must ensure multiple use of the data accumulated for solving various applied problems, minimizing the costs of searching and processing data;

– efficacy: ensuring maximum satisfaction of the needs of the digital platform users with the constant increase in the number of users and the number of problems to be solved, along with the continuous minimization of the costs required to quickly achieve meaningful results.

Features of using the cascade diagram of health changes

The use of the cascade diagram of health changes is fully consistent with the concept of 4P-medicine; it ensures:

– prediction and prevention of diseases due to implementation of health risk monitoring and the possibility of risk management through preliminary risk minimization (the second cascade

of the diagram) and minimization of the risk factor effects (the third cascade of the diagram);

– healthcare personalization due to the possibility of individual monitoring of health changes;

– participative nature of healthcare due to the possibility of ensuring the patient's direct involvement in management of health changes through informing about the health risk and ways (methods, technologies) to minimize it.

The use of the cascade diagram of health changes is fully consistent with the data-driven management principle; it makes allows one to:

– implement continuous monitoring of health risk in representatives of all social and professional groups based on combining the results of health monitoring at the individual and population levels;

– ensure the a priori high potential efficacy of the implementation of health preservation and maintenance measures due to the possibility to calculate the doses of risk factors and health risk by "connecting", "disconnecting", and changing the characteristics of the second and third diagram cascade blocks.

CONCLUSION

The study has shown the feasibility of using the cascade diagram of occupational health changes to solve the problems of health risk monitoring during implementation of the digital platform for human health shaping, maintenance, and preservation. For that it is necessary to expand the range of the health risk minimization cascade and risk factor effect minimization cascade blocks in order to consider all the health risk minimization potentialities, as well as to develop methodological support of the risk factor dose and health risk calculation in order to cover the larger number of social and professional population groups.

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