DOI: https://doi.org/10.15407/kvt206.04.073

УДК: 615.47: 004.9

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MOBILE AI-TECHNOLOGY FOR FORMING THE PERSONALIZED MOVEMENT REHABILITATION PLAN AFTER A STROKE

Introduction. *The consequences of stroke seriously change the quality of life. Especially suffers motor activity. Speech disorders occupy a significant place. Synthesis of effective technologies for recovery of the movements, fine motor skills of the hand, which plays a significant role in recovering the speech motility, is an the urgent scientific and applied task.*

Recently, the use of artificial intelligence (AI) in medicine has attracted attention. At the same time, mobile technologies are being developed. It is believed that AI in a smartphone will make the medicine of the future accessible to all.

The purpose of the paper *is to develop a technology for movement recovery after a stroke which uses the AI tool to increase the effectiveness of rehabilitation process. This AI tool is a specialized software module for mobile platforms, which assists the user (physician) in creating personalized plans at different rehabilitation stages.*

Results. *An AItechnology for creating a personalized movement training plan in patient after a stroke has been developed. This technology uses AI tool. The software module for information assistance in creating the plan "MovementRehabStroke 1.0 (MD)" installed on mobile platforms. This module provides the user with recommended movement training plan based on the results of quantitative assessment of movement disorders and the patient's general state. These disorders are determined by the software module "MovementTestStroke 1.1 (MD)". If necessary, this plan may be corrected by the user (physician).*

The structural and functional model of interaction of the user (physician) and software module "MovementRehabStroke 1.0 (MD)" is presented, and the algorithm for creating the personalized movement training plan, recommended and finally corrected by the user, is provided.

Conclusions. *The application of AI tools will help to reduce the physician's error in making diagnostic and treatment decisions, prevent complications, reduce the risk of acquired disability, and will improve the quality and widespread usage of medical and rehabilitation services for patients after a stroke.*

Keywords: *stroke, AI-technology, personalized plan, movement training, rehabilitation, diagnostics, software module, structural and functional model, algorithm.*

INTRODUCTION

Stroke is a common neurological disease and the leading cause of chronic disability worldwide. It is accompanied by various complications, including motor, speech, visual, perception and cognition disorders, and paresthesia. Stroke seriously affects the quality of daily life.

The increase of stroke severity among people of working age is of concern. Motor activity disorders, such as paralysis, paresis, problems with coordination, muscle hypertone, loss of sensitivity in the arms and legs are some of the main consequences of a stroke. According to the World Health Organization, 80 % of stroke survivors have varying degree of extremity dysfunction, and more than 60 % of them still have upper extremity dysfunction after the transition to a chronic phase.

Of high importance are also speech disorders, among which the most frequent is motor aphasia caused by damage to motor speech zone of cerebral cortex, where the motor program of speech is formed [1–8]. The number of people who need the rehabiliation after a stroke is growing rapidly, and the costs and pressure on medical budgets increase too [9, 10]. The quality care for stroke survivors can significantly reduce the risk of acquired disability. The synthesis of effective technologies for personalized restoration of voluntary extremity movements, including fine motor skills of the hand, which plays a significant role in restoring the speech motor skills [11], is the actual scientific and applied task.

Lately, more and more attention is paid to applying an artificial intelligence (AI) in medicine [12]. The Oxford Dictionary defines AI as the theory and development of computer systems that capable to perform the tasks that typically require human intelligence [13]. "AI is poised to play an increasingly prominent role in medicine and healthcare because of advances in computing power, learning algorithms and the availability of large datasets (big data) sourced from medical records and mobile health monitors" [14]. It is believed that AI in a smartphone will make the medicine of future accessible to everyone. Any mobile phone user will have a personal medical assistant, capable of solving problems related to an individual's health in real time. AI is already able to greatly facilitate the work of health professionals, increase the diagnostics accuracy and help patients to cope with everyday tasks [8, 15]. Computers can be programmed to make decisions in real situations. The integration of machines, software and specific information allows the system to transmit thought process, explanation and advice to the end-user [13–15].

Utilisation of AI tools will increase effectiveness and mass usage of rehabilitation services for patients after a stroke, and will improve the quality of these services. In particular, AI tools can be used for personalization and expansion of rehabilitation process functionality aimed at restoring the motor and, indirectly, speech functions, reducing the user's (physician's) error, and for personalization of preventive and rehabilitation measures based on disorders specifics.

The main purpose of the rehabilitation process is the utilization of methods and tools, which mobilize, trigger and strengthen patient's reserves, aimed at recovering the functions damaged by pathology, in accordance with their state at each rehabilitation stage, taking into account the patient's general state, concomitant diseases, etc.

Regarding the movement recovery, the reserves mobilization involves development and realization of the individual complex rehabilitation plans, where, along with medication, the programmed electromyostimulation as a method of training forced muscle contractions by certain programs, as well as by biological feedback (biofeedback) as a training method of voluntary muscle contractions. Innovative TRENAR® technology, which is implemented by portable electronic devices TRENAR-01 and TRENAR-02, uses a set of original programs for movement training by methods of programmed electrical stimulation and biofeedback. The general advantage of these programs is a combination of physical and cognitive influences that trigger and stimulate the patient's reserves to recover the movement and involve a patient in the training process, thus increasing the rehabilitation effectiveness.

The purpose of the paper is to create intelligent information technology to design a personalized rehabilitation plan after a stroke that uses AI tool for increasing the effectiveness of rehabilitation process. This AI tool is a specialized software module for Android mobile platforms to assist the user (physician) in designing a personalized plan. This plan consists of the method, program, movements and training duration with using TRENAR® devices.

To assist the user (physician) with rehabilitation decision-making, the specialized program module for designing personalized rehabilitation plans "MovementRehabStroke 1.0 (MD)" is used. This module provides the user with recommended movement training plan based on the results of the quantitative assessment of movement disorders, determined by the software module "MovementTestStroke 1.1 (MD)", and taking into account patient's neurological status, concomitant diseases, etc.

THE STRUCTURAL AND FUNCTIONAL MODEL OF THE USER AND SOFTWARE MODULE INTERACTION TO CREATE THE PERSONALIZED MOVEMENT TRAINING PLANS FOR MOBILE PLATFORMS

Creation of the personalized training plan using the AI tool, the specialized software module "MovementRehabStroke 1.0 (MD)" for mobile platforms, which provides information and consulting assistance to a physician in creating the personalized training plans for patients after a stroke, is provided and described on structural and functional model (Fig. 1).

This software module consists of the graphical user interface (GUI) and the main information units: I — Database, II — Unit for quantitative assessment of movement disorders "MovementTestStroke 1.1 (MD)" (hereinafter — Unit for movement diagnostics), III — Unit for creating the personalized movement training plans (Fig. 1).

These units are combined with a GUI that provides the user with a dialog mode of interaction with them:

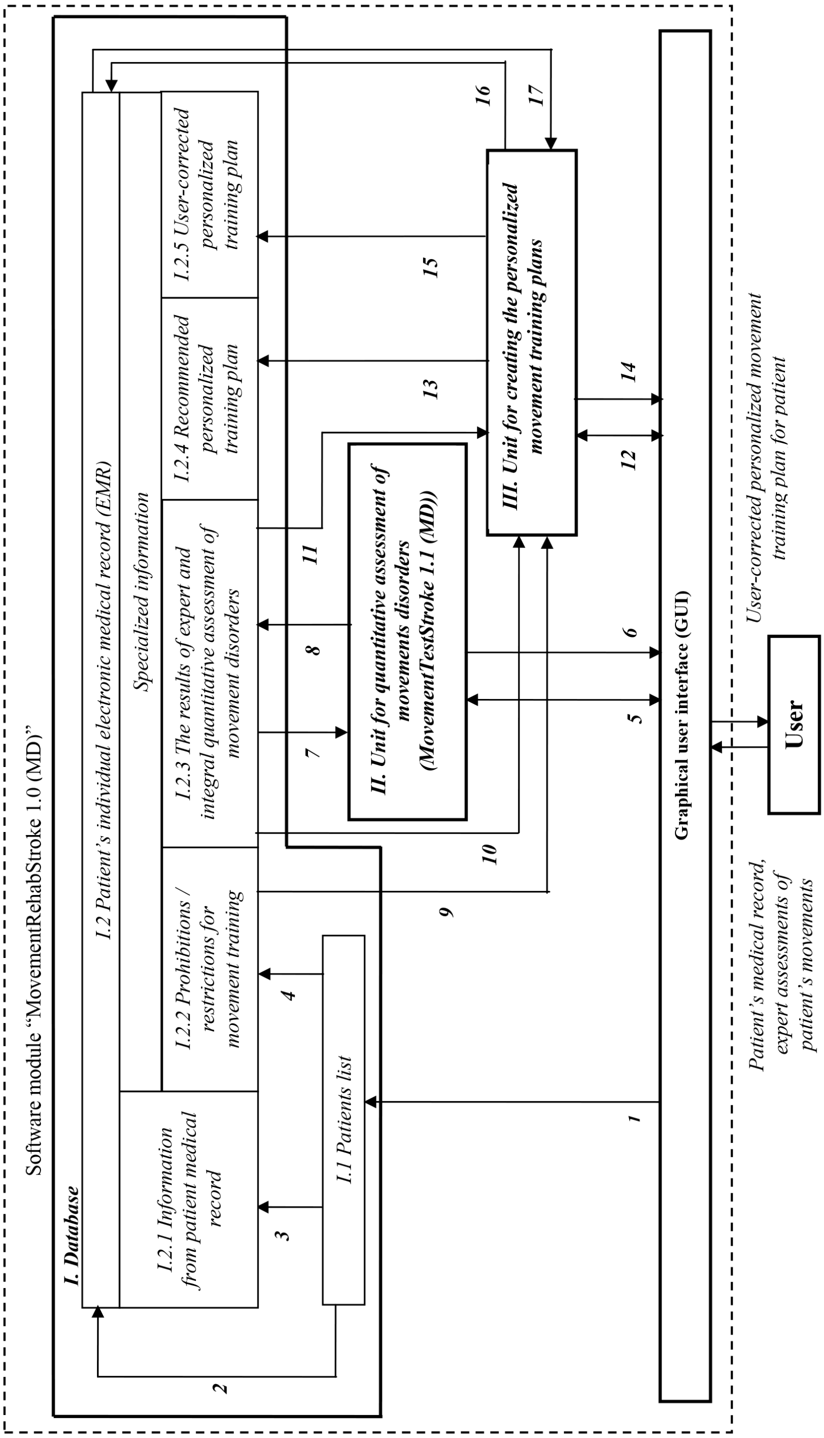

Fig. 1. Structural and functional model of the user and software module "MovementRehabStroke 1.0 (MD)" interaction (markings are in the text)

— inputting the patient's express information and information about a patient's general state in the Database (1);

— providing the access to the patient's individual electronic medical record (EMR) in the Database (2);

— inputting the information from the patient's medical record about the patient's general state, in particular the neurological status and concomitant diseases, in the Database (3);

— marking the concomitant factors of the patient that prohibit or restrict the patient's movement training (4);

— selecting the movement testing object (extremity, hand, gait) and evidence criteria for its assessment, selecting the right verbal characteristic on the assessment scale by selected evidence criterion, outputting the quantitative indicator of motor functions disorders in points by selected evidence criterion (5);

— outputting to the user (physician) the general results of distributed expert and integral quantitative assessment of movement, and movement recovery effectiveness (6);

— loading the data of integral quantitative assessment in points from the first test to assess the movement recovery effectiveness (7);

— storing the current results of distributed expert and integral quantitative assessment of movement in points in the Database (8);

— loading the information from the patient's medical record (9), information on prohibition / restriction for patient's movement training (10), the results of distributed expert assessment of movement disorders for current test from the Database (11) to create the recommended movement training plan for the patient;

— notifying on inability of the patient's movement training; outputting the recommended personalized movement training plan to the user; user's correction of the personalized training plan by selecting the specific movements, methods, programs in the recommended plan (12);

— storing the recommended personalized movement training plan in the Database (13);

— outputting the created recommended personalized movement training plan and the patient's information to the user (14);

— storing the user-corrected personalized movement training plan in the Database (15);

— sending the request to Database to display patient's information (16);

— loading the patient's information from Database (17).

Information unit I, "*Database*", is designed for storing the information about each patient who has already passed or is passing the rehabilitation for the first time. It contains two main components: *I.1* "*Patients list*" and *I.2* "*Patient's individual electronic medical record*".

Component *I.1* is formed in the tabular list view. Each patient on the list is represented by the express information record (hospitalization date, patient's surname-initials-sex, medical record number, physician's surname) according to the standard (form 003/o "Medical record of the in-patient"). The user checks (1) the presence of the right patient. If the patient is absent, the user adds (1) to the Database this patient's express information from the medical record. The presence of a patient on the list makes it possible to provide (2) the access to his individual EMR in the *Database*.

From the medical record the user inputs (3) information about the patient's general state (indicators of neurological status, concomitant diseases, etc.) in the cluster *I.2.1* "*Information from patient's medical record*" of the *Database*.

Component *I.2* of the *Database* receives the specialized information:

— the user-marked (4) prohibition / restriction factors of movement training (e.g., acute period of illness, diabetes mellitus on decompensation, the artificial cardiac pacemaker presence, etc.) are stored in the cluster *I.2.2 "Prohibitions / limitations for movement training"* of the *Database*;

— the results of expert and integral quantitative assessment of movement disorders before and after rehabilitation (8) from the *information unit II* (Unit for movement diagnostics) are stored in the cluster *I.2.3 "The results of expert and integral quantitative assessment of movement disorders"* of *Database*;

— recommended and user-corrected personalized movement *training* plans from *information unit III* (*Unit for creating the personalized movement training plans*) are respectively stored in the clusters *I.2.4 "Recommended personalized training plan"* and *I.2.5 "User-corrected personalized training plan"* of the *Database*;

Information unit II, the *Unit for movement diagnostics* (Software module for quantitative assessment of movement disorders "MovementTestStroke 1.1 (MD)" [16]), is designed for distributed expert and integral quantitative assessment based on relevant scales of the Protocol for quantitative assessment of movement disorders of a patient after a stroke [16, 17]:

— by main evidence criteria (muscle strength, volume of movements) [18] of movement disorders of upper and lower extremities at the level of individual joint in proximal (2 joints) and distal (1 joint) parts;

— by additional evidence criteria, such as fine motor skills of the hand (contrasting the thumb, flexing the hand's fingers in fist, the hand's main motor function (capturing), the hand's fingers extension) and structure of walking [17, 19];

— of muscle hyper- or hypotone [17, 18].

Also, the integral quantitative assessments at the level of one joint of aforementioned parts of upper and lower extremities or hand are calculated, and the movement recovery effectiveness are determined.

The functional purpose of the *Unit for movement diagnostics* is a separate presentation of movement testing objects (extremity, hand, gait) and the evidence-based evaluation criteria in tabular form. The movement disorders at the level of the joint of the proximal and distal parts of the upper and lower extremities, fine motor skills of the hand and the gait can be assessed by choice.

In this unit the user selects movement testing object and the evidence criteria of its assessment (5). Depending on the testing object the relevant assessment scales are loaded according to the selected evidence criteria. Based on the scale, the user chooses the right verbal characteristic of this criterion, which allows the program to assess and display on the GUI the quantitative indicator of the movement disorders in points (5).

Summarized results of distributed expert and integral quantitative assessment of movement disorders for current test are displayed for all chosen testing objects (6).

If test of the patient's movements is performed not for the first time in the rehabilitation course, integral assessments of movement disorders from the first test are automatically uploaded (7) to the *Unit for movement diagnostics* from the cluster *I.2.3* of the *Database*. By comparing the integral assessments for the current and first tests in unit II, the movement recovery effectiveness are calculated, and also are output (6) to the user.

The results of the distributed expert and integral quantitative assessment of movement disorders for current test, and the movement recovery effectiveness are stored (8) in the cluster *I.2.3* of the *Database*.

It should be noted that in contrast to the PC version [20] there is no function for creating the *dynamics of the results of movement tests* in the information unit II (*Unit for movement diagnostics*). In addition, the limitation of the screen size of mobile devices causes a difference in the algorithms of interaction between the user and the information units.

Information unit III, the *Unit for creating the personalized movement training plans,* is used to create the personalized movement training plan, which activates additional patient's reserves for movement rehabilitation according to the severity of movement function disorders and the general state of the patient. The following information is uploaded to this unit from the *Database*:

from cluster *I.2.1,* the information on the neurological status, concomitant diseases, state of emotional and volitional sphere (9);

from cluster *I.2.2,* the prohibition / restriction factors for movement training (10);

from cluster *I.2.3,* the results of distributed expert and integral quantitative assessment of movement disorders for the current test (11), which differs from the PC version [20], where these results come to this unit directly from the *Unit for movement diagnostics*.

According to the relevant decision-making rules, this unit provides the permission / restriction / prohibition for movement training based on certain factors, the determination of permitted movements, methods, programs and movement training duration based on quantitative expert assessment of patient's movement disorders; the correction of these indicators with taking into account concomitant diseases and the state of emotional and volitional sphere; the distribution of the methods, programs, movements and their training duration by priority.

Giving the priority to method, training program comes from the principle of biologically adequate activation of additional patient's reserves to recovery movement at the current rehabilitation stage of the patient [21]. The priority for movement depends on the severity of movement disorders. However, if the patient has elements of motor aphasia, training of the fine motor skills of the hand gets a higher priority. The main factors, determing the training duration, are concomitant diseases, the state of emotional and volitional sphere, individual sensitivity to electrical stimulation, etc.

If there are factors prohibiting completely movement training, the user is notified and the session with the patient ends (12). In case of movement training restrictions, the program continues to work taking into account these restrictions.

The recommended personalized training plan according to priority of its components (methods, programs, movements and their training duration) is displayed on the GUI for the user (12) and is also stored (13) in cluster *I.2.4*, "*Recommended personalized rehabilitation plan*",of the *Database*.

The user checks (12) the recommended personalized plan and marks in this plan specific movements, methods, movement training programs, i.e. creates a personalized plan for movement training at a certain rehabilitation stage.

Next, the user-corrected personalized plan is stored (15) in the cluster *I.2.5*, "*User-corrected personalized rehabilitation plan*", of *Database*, and is also displayed to the user (14).

According to the created personalized plan, the user begins to train the patient's movements at a certain rehabilitation stage. After completing the movement training sessions, the user diagnoses the patient's movements and determines the rehabilitation effectiveness [20].

ALGORITHM FOR CREATING A PERSONALIZED MOVEMENT TRAINING PLANS WITH A SPECIALIZED SOFTWARE MODULE FOR MOBILE PLATFORMS

Creating a personalized recommended and user-corrected movement training plans is based on the results of quantitative assessment of movement disorders taking into account the patient's general state (neurological status, concomitant diseases, the state of emotional and volitional sphere, etc.).

The algorithm for creation of these plans with the specialized software module "MovementRehabStroke 1.0 (MD)" is aimed at providing the information and consulting assistance to the physician in forming the movement training plan of the patient after a stroke (Fig. 2–4).

According to the structural and functional model (Fig. 1) the creation of the personalized plans begins with *I. Operating with Database* (Fig. 2): loading the patients list, checking the presence of right patient on the list by the user (physician).

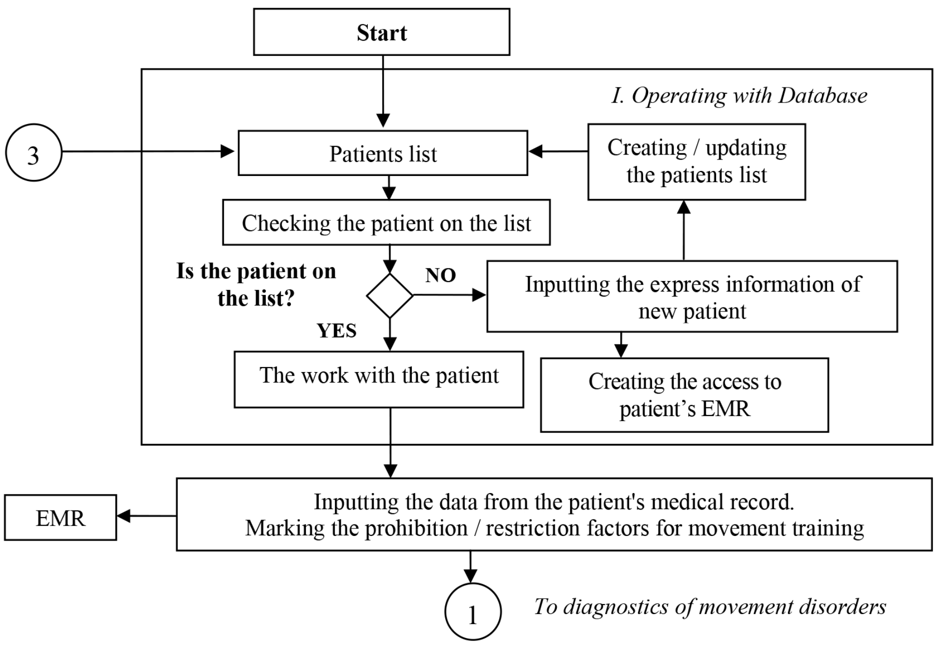

Fig. 2. Algorithm for creating a personalized movement training plans: Operating with Database, Inputting the data from the patient's medical record

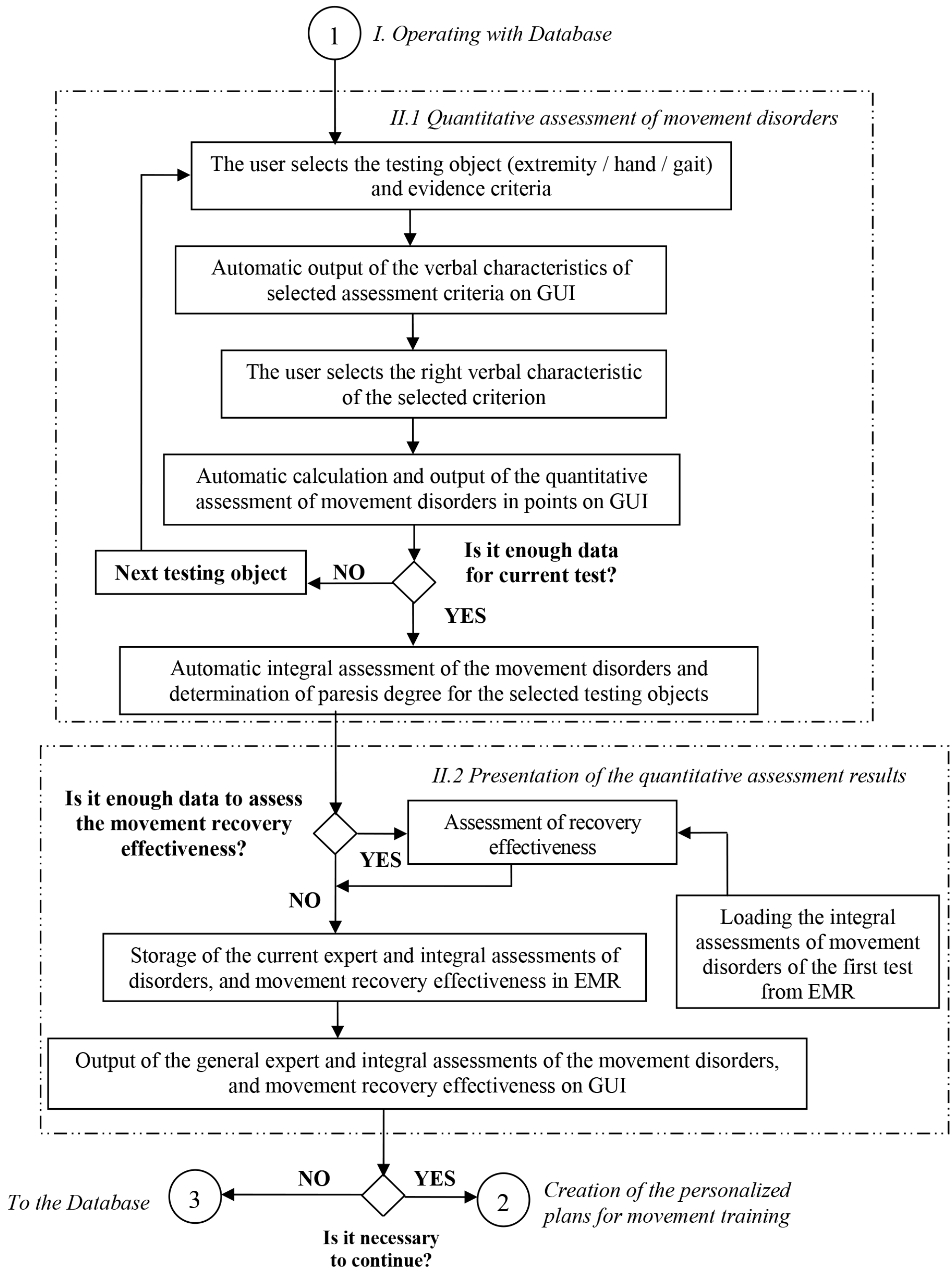

Fig. 3. Algorithm for creating the personalized movement training plans: diagnostics of movements disorders with an information unit for quantitative assessment of movement disorders ("MovementTestStroke 1.1 (MD)" software module)

If the list isn't yet created or such patient is absent, the user inputs express information from patient's medical record for creating / updating the patients list. At the same time, the access to patient's individual EMR is created. The user returns to the updated list.

Then the user inputs the information from the patient medical record (Fig. 2): neurological status, emotional state, concomitant diseases, as well as marks the prohibition / restriction factors for movement training in case of their presence. The information is stored in the patient's EMR.

After that the user moves to *II. Diagnostics of movement deficit*, which is performed by software module «MovementTestStroke 1.1 (MD)» [16]. The algorithm of diagnostics is separated on two parts: *II.1 Quantitative assessment of movement disorders,* and *II.2 Presentation of the results of quantitative assessment* (Fig. 3).

The presentation of the results of quantitative assessment includes determining the movement recovery effectiveness and outputting the results for current movement test.

In case of insufficient data in current test, the user proceeds to another testing object. Otherwise, for selected testing objects the integral assessments of disorders are calculated, and the paresis degrees are determined. Then there is crossing to *II.2 Presentation of the results of quantitative assessment*.

The presentation of the results of quantitative assessment includes determining the movement recovery effectiveness and outputting the results for current movement test.

In case of sufficient information for assessing the movement recovery effectiveness of selected testing objects, the integral assessments of movement disorders for these objects from the first test are loaded from relevant component of EMR. The effectiveness is determined by comparing the integral assessments for the current and first tests, and isn't determined in case of data absence of the first test for selected testing object.

The results for current test and movement rehabilitation effectiveness (in case of its presence) are stored in individual EMR and are displayed by program on the GUI.

The patient session ends if only a quantitative assessment of movement disorders is required, and the user returns to patients list. Otherwise, the user creates the personalized movement training plans.

In case "*III. Creation of personalized movement training plans"* (Fig. 4) there is a check of the permission / restriction / prohibition to perform the training based on prohibition / restriction factors for movement training. If there is a movement training prohibition, the patient session ends and the user is notified on prohibition.

Creating the personalized movement training plan continues in case of training permission. The recommended personalized movement training plan (distributed by priority the permitted movement, methods, programs and movement training duration) is output to the user. This plan is stored in the patient's EMR.

After reviewing the plan, the user corrects it: marks the specific movements, methods, programs. At the same time, user's choice is based on patient's information, which can be viewed optionally. The personalized user-corrected plan is also stored in the patient's EMR and is displayed to the user. If the user doesn't approve this plan, it is possible to correct it with rewriting in the patient's EMR. Finally the patient's personalized user-corrected movement training plan is that plan, according to which the movements are trained at this rehabilitation stage.

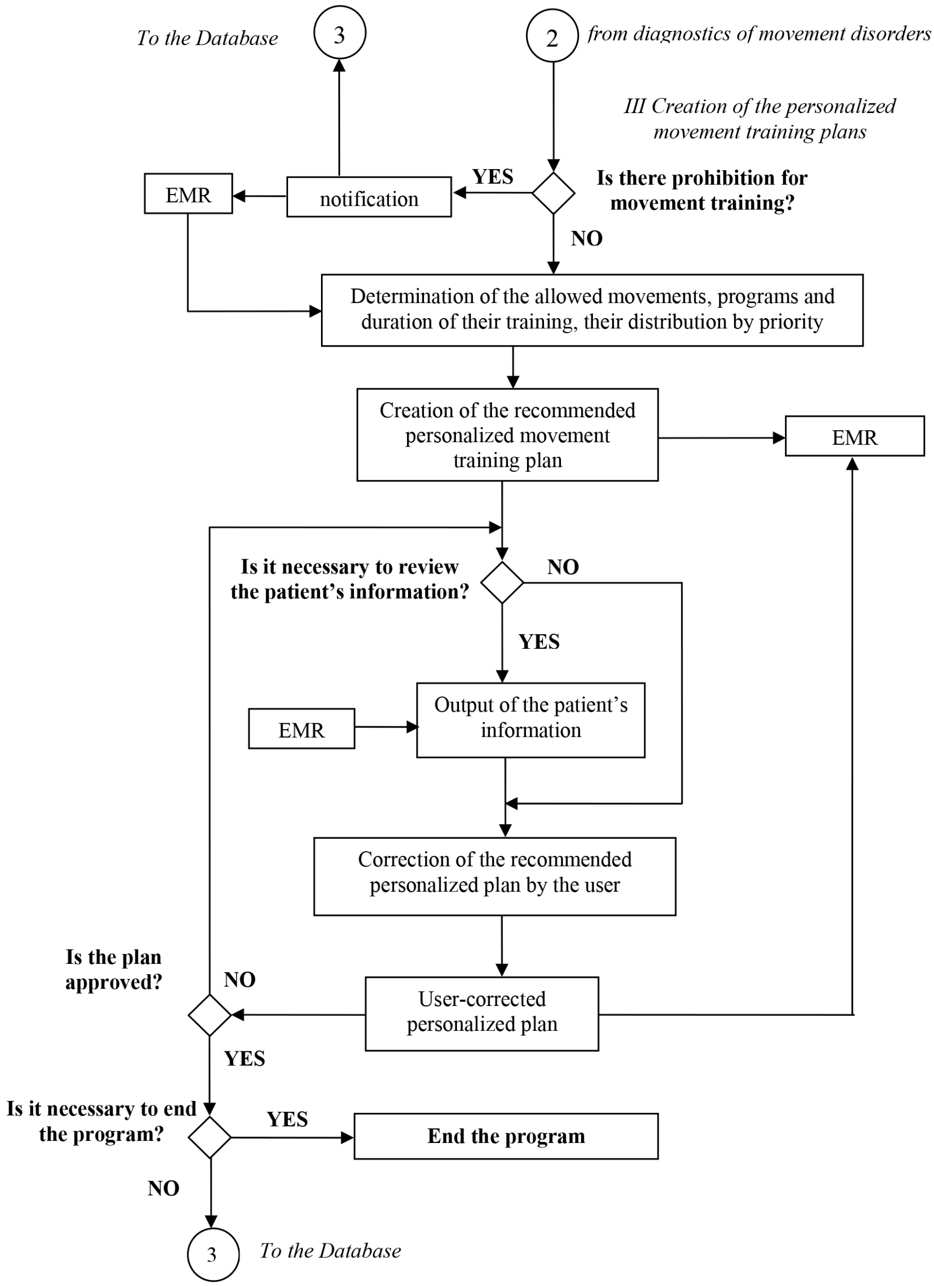

Fig. 4. Algorithm for creating a personalized movement training plans: recommended and user-corrected movement training plans

Then the user either ends the session with the current patient and returns to patients list (Database) or ends the program.

It should be noted that the created personalized movement training plan at a certain stage of rehabilitation course needs to be updated at the following stages.

The patient's rehabilitation course ends with assessment of rehabilitation effectiveness, i.e. comparing the quantitative assessment of movement disorders at the end and at the beginning of the rehabilitation course by the information unit of quantitative assessment of movement disorders "MovementTestStroke 1.1 (MD)".

The feature of the software module "MovementRehabStroke 1.0 (MD)" is that it can be used both to create a personalized movement training plan depending on the quantitative assessment of movement disorders, and only to diagnose the motor function disorders at different rehabilitation stages with the help of information unit "MovementTestStroke 1.1 (MD)".

CONCLUSION

The AItechnology for creating a personalized movement *training* plan for patients after a stroke has been developed. The technology is designed for Android mobile platforms. In order to increase the effectiveness of the rehabilitation process we utilized the the AI tool, the specialized software module "MovementRehabStroke 1.0 (MD)", which provides the information assistance to the user (physician) in creating the personalized training plan. The personalized plan is a multicriteria prioritization of the recommended movements and their training duration, as well as methods and programs of training with using TRENAR® devices. Movement training according to this plan provides the activation of the patient's reserves to recover movements, as well as speech motility based on training the fine motor skills of the hand, depending on severity of movement disorders, neurological status, psycho-emotional status, concomitant diseases and rehabilitation stage.

The theoretical basis of the synthesis of AI-technology is the phenomenon of neuroplasticity [22], and principle of personal activation of the patient's reserves to recover movements damaged by pathology (in particular a stroke) [21]. According to this principle, a structural and functional model of the user (physician) interaction with the software module for information assistance in creating the personalized movement training plan after a stroke for mobile platforms "MovementRehabStroke 1.0 (MD)" has been developed.

The module's structure consists of main information units: Database, where information about the patient is stored, the Unit for quantitative assessment of movement disorders by software module "MovementTestStroke 1.1 (MD)", the Unit for creating the personalized movement training plans, recommended and finally corrected by the user, and a GUI that allows the user to work in dialog mode with information units.

The practical basis of synthesis is an algorithm for creating the personalized movement training plans, recommended and finally corrected by the user.

The developed AItechnology enables:

— creation of the personalized movement training plans, recommended and finally corrected by user, and their review on the interface;

— determination of the rehabilitation effectiveness based on quantitative assessment of movement disorders before and after the movement training;

— storage of complete information about a patient (neurological status, concomitant diseases, psycho-emotional state, etc.), assessments of movement disorders before and after the movement training and rehabilitation effectiveness, and movement training plans in the individual EMR of the Database.

Advantages:

— reduction the physician error in diagnostic and treatment decisions;

— the ability to identify the specifics of movement disorders after a stroke;

— personalization of preventive and rehabilitation measures based on advanced functional capabilities for movement disorders diagnostics (distributed and integral quantitative assessment based on evidence criteria at the level of joints of proximal and distal parts of upper and lower extremities, fine motor skills of the hand and gait).

The results of the research enable the creation of new competitive tools of mobile digital medicine to solve urgent problems of quality care for patients after a stroke, the provision and monitoring of rehabilitation and health services not only in clinics but also at home, as well as and enable utilization of new information technologies with AI tools in educational programs.

REFERENCES

1. Gorelick P.B. The global burden of stroke: Persistent and disabling. *Lancet Neurol.* 2019. Vol. 18. № 5. pp. 417–418.
2. Delpont B., et.al. Pain after stroke: A review. *Revue neurologique*. 2018. Vol. 174. № 10. pp. 671–674.
3. Buono Lo, Corallo F., Bramanti P., Marino S. Coping strategies and health-related quality of life after stroke. 2017. *J. Health Psychol.* 2017. Vol. 22. № 1. pp. 16–28.
4. Jorgensen H.S., Nakayama H., Raaschou H.O., Olsen T.S. Recovery of walking function in stroke patients: the Copenhagen Stroke Study. *Archives of Physical Medicine and Rehabilitation*. 1995. Vol. 76(1). pp. 27–32.
5. Holland A., Fridriksson J. Aphasia management during the early phases of recovery following stroke. *American Journal of Speech-Language Pathology*. 2001. Vol. 10 (1). pp. 19–28.
6. Berthier M.L. Poststroke aphasia: epidemiology, pathophysiology and treatment. *Drugs Aging*. 2005. Vol. 22(2). pp. 163–182.
7. Hatem S.M., Saussez G., Faille M.D., Prist V. Rehabilitation of motor function after stroke: A multiple systematic review focused on techniques to stimulate upper extremity recovery. *Frontiers Hum. Neurosci.* 2016. Vol. 10. P. 442.
8. Upper Limb Rehabilitation System for Stroke Survivors Based on Multi-Modal Sensors and Machine Learning / Sheng Miao, et.al. *IEEE Access: Special section on AI and IoT convergence for smart health*. 2021. Vol. 9. pp. 30283–30291.
9. Hossain M.S. Cloud-supported cyber-physical localization framework for patients monitoring. *IEEE Syst. J.* 2015. Vol. 11. № 1. pp. 118–127.
10. Stinear C.M., Lang C.E., Zeiler S., Byblow W.D. Advances and challenges in stroke rehabilitation. *Lancet Neurol.* 2020. Vol. 19. № 4. pp. 348–360.
11. Vovk M.I., Galyan Ye.B. Restoring of motor component of speech based on muscle movement control. Theoretical grounding. *Cybernetics and Computer Engineering*. 2012. № 167. pp. 51–60. (in Russian).

12. Varun H Buch, Irfan Ahmed, Mahiben Maruthappu. Artificial intelligence in medicine: current trends and future possibilities. *Br J Gen Pract*. 2018. № 68(668). pp. 143–144.
13. The Oxford Dictionary of Current English. Oxford: Oxford University Press, 2001. 3rd edition. 1083 p.
14. Ahuja A.S. The impact of artificial intelligence in medicine on the future role of the physician. *PeerJ*. 2019. URL: http://doi.org/10.7717/peerj.7702 (Last accessed: 01.09.2021)
15. Artificial intelligence in medicine: the main trends in the world. URL:https://medaboutme.ru/zdorove/publikacii/stati/sovety_vracha/iskusstvennyy_intellekt_v_meditsine_glavnye_trendy_v_mire/ (Last accessed: 1.04.2021) (in Russian).
16. Vovk M.I., Kutsiak O.A. AI-Technology of Motor Functions Diagnostics after a Stroke. *Cybernetics and Computer Engineering*. 2021. № 2 (204). pp. 84–100.
17. Vovk M.I., Kutsyak O.A. Software module for personal diagnostics of motor functions after stroke. *Cybernetics and Computer Engineering*. 2019. № 4 (198). pp. 62–77.
18. Belova A., Shchepetova O. Scales, tests and questionnaires in medical rehabilitation. Moscow: Antidor, 2002. 440 p. (in Russian)
19. Smychek V., Ponomareva E. Craniocerebral trauma (clinic, treatment, examination, rehabilitation). Minsk: Research Institute of ME and R, 2010. 430 p. (in Russian)
20. Vovk M.I., Kutsyak O.A. Information technology for forming a personal movement rehabilitation plan after a stroke. *Cybernetics and Computer Engineering*. 2020. № 3 (201). pp. 87–99.
21. Vovk M.I. Information technology of movement control. Evolution of synthesis and development prospects. *Cybernetics and Computer Engineering*. 2018. № 4 (194). pp. 79–97. (in Ukrainian).
22. Ugryumov M.V. Compensatory capabilities of the brain. URL: http://www.den-za-dnem.ru/page.php?article=576s (Last accessed: 01.09.2021) (in Russian)

Received 15.09.2021

ЛІТЕРАТУРА

1. Gorelick P.B. The global burden of stroke: Persistent and disabling. *Lancet Neurol.* 2019. Vol. 18. № 5. pp. 417–418.
2. Pain after stroke: A review / B. Delpont, et.al. *Revue neurologique*. 2018. Vol. 174. № 10. pp. 671–674.
3. Buono Lo, Corallo F., Bramanti P., Marino S. Coping strategies and health-related quality of life after stroke. 2017. *J. Health Psychol.* 2017. Vol. 22. № 1. pp. 16–28.
4. Jorgensen H.S., Nakayama H., Raaschou H.O., Olsen T.S. Recovery of walking function in stroke patients: the Copenhagen Stroke Study. *Archives of Physical Medicine and Rehabilitation*. 1995. Vol. 76(1). pp. 27–32.
5. Holland A., Fridriksson J. Aphasia management during the early phases of recovery following stroke. *American Journal of Speech-Language Pathology*. 2001. Vol. 10 (1). pp. 19–28.
6. Berthier M.L. Poststroke aphasia: epidemiology, pathophysiology and treatment. *Drugs Aging*. 2005. Vol. 22(2). pp. 163–182.
7. Hatem S.M., Saussez G., Faille M.D., Prist V. Rehabilitation of motor function after stroke: A multiple systematic review focused on techniques to stimulate upper extremity recovery. *Frontiers Hum. Neurosci.* 2016. Vol. 10. P. 442.
8. Upper Limb Rehabilitation System for Stroke Survivors Based on Multi-Modal Sensors and Machine Learning / Sheng Miao, et.al. *IEEE Access: Special section on AI and IoT convergence for smart health*. 2021. Vol. 9. pp. 30283–30291.
9. Hossain M.S. Cloud-supported cyber-physical localization framework for patients monitoring. *IEEE Syst. J.* 2015. Vol. 11. № 1. pp. 118–127.
10. Stinear C.M., Lang C.E., Zeiler S., Byblow W.D. Advances and challenges in stroke rehabilitation. *Lancet Neurol.* 2020. Vol. 19. № 4. pp. 348–360.
11. Вовк М.И., Галян Е.Б. Восстановление моторного компонента речи на базе управления мышечными движениями. Теоретическое обоснование. *Кибернетика и вычисл. техника*. 2012. № 167. С. 51–60.

12. Varun H Buch, Irfan Ahmed, Mahiben Maruthappu. Artificial intelligence inmedicine: current trends and future possibilities. *Br J Gen Pract*. 2018. № 68(668). pp.143–144.
13. The Oxford Dictionary of Current English. Oxford: Oxford University Press, 2001. 3rd edition. 1083 p.
14. Ahuja A.S. The impact of artificial intelligence in medicine on the future role ofthe physician. *PeerJ*. 2019. URL: http://doi.org/10.7717/peerj.7702 (Дата звернення: 01.09.2021)
15. Искусственный интеллект в медицине: главные тренды в мире. URL: https://medaboutme.ru/zdorove/publikacii/stati/sovety_vracha/iskusstvennyy_intellekt_v_meditsine_glavnye_trendy_v_mire/ (Дата звернення: 1.04.2021)
16. Vovk M.I., Kutsiak O.A. AI-Technology of Motor Functions Diagnostics after a Stroke. *Cybernetics and Computer Engineering*. 2021. № 2 (204). pp. 84–100.
17. Vovk M.I., Kutsyak O.A. Software module for personal diagnostics of motor functions after stroke. *Cybernetics and Computer Engineering*. 2019. № 4 (198). pp. 62–77.
18. Белова А., Щепетова О. Шкалы, тесты и опросники в медицинской реабилитации. М.: Антидор, 2002. 440 с.
19. Смычек В., Пономарева Е. Черепно-мозговая травма (клиника, лечение, экспертиза, реабилитация). Мн.: НИИ МЭ и Р, 2010. 430 с.
20. Vovk M.I., Kutsyak O.A. Information technology for forming a personal movement rehabilitation plan after a stroke. *Cybernetics and Computer Engineering*. 2020. № 3 (201). pp. 87–99.
21. Вовк М.І. Інформаційна технологія керування рухами. Еволюція синтезу і перспективи розвитку. *Кибернетика и вычислительная техника*. 2018. № 4 (194). С. 79–97.
22. Угрюмов М.В. Компенсаторные возможности мозга. URL: http://www.den-za-dnem.ru/page.php?article=576s (Дата звернення: 01.09.2021)

Отримано 15.09.2021

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МОБІЛЬНА AI-ТЕХНОЛОГІЯ ФОРМУВАННЯ ПЕРСОНАЛІЗОВАНОГО ПЛАНУ РЕАБІЛІТАЦІЇ РУХІВ ПІСЛЯ ІНСУЛЬТУ

Вступ. Наслідки інсульту серйозно змінюють якість життя. Особливо страждає рухова активність. Вагомими є також мовленнєві порушення. Синтез ефективних технологій відновлення рухів, тонкої моторики кисті, яка відіграє значну роль у відновленні моторики мовлення, є актуальним науково-прикладним завданням.

Останнім часом у медицині увагу привертає застосування штучного інтелекту**.** Одночасно розвитку набувають мобільні технології. Вважають, що штучний інтелект у смартфоні зробить медицину майбутнього доступною для всіх.

Мета — розроблення технології відновлення рухів після інсульту, в якій для підвищення ефективності реабілітаційного процесу застосовано інструмент штучного інтелекту — встановлений у структурі мобільних платформ спеціалізований програмний модуль інформаційної допомоги користувачу (лікарю) у формуванні персоналізованого плану на різних етапах реабілітації.

Результати. Розроблено АІ-технологію формування персоналізованого плану тренувань рухів у пацієнтів після інсульту із застосуванням інструментів штучного інтелекту — встановленого у структурі мобільних платформ програмного модуля інформаційної допомоги у визначенні плану «MovementRehabStroke 1.0 (MD)», який за результатами кількісного оцінювання дефіциту рухів пацієнта програмним модулем «MovementTestStroke 1.1 (MD)» з урахуванням загального стану пацієнта надає користувачу рекомендований план та уможливлює його коригування. Надано структурно-функційну модель взаємодії користувача (лікаря) з програмним модулем «MovementRehabStroke 1.0 (MD)», а також алгоритм формування персоналізованого плану реабілітації рухів — рекомендованого та остаточно сформованого лікарем.

Висновки. Застосування інструментів штучного інтелекту сприятиме: зменшенню можливості помилки лікаря у прийнятті діагностично-реабілітаційних рішень, запобіганню розвитку ускладнень, зменшенню ризику набутої інвалідності, уможливить підвищення якості та масове використання реабілітаційних послуг пацієнтами після інсульту.

***Ключові слова**: інсульт, АІ-технологія, персоналізований план, тренування рухів, реабілітація, діагностика, програмний модуль, структурно-функційна модель, алгоритм.*