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INFORMATION TECHNOLOGY TEACHING THE METHODS FOR THE ORGANISM RECOVERY AT HOME CONDITIONS

The information technology that provides learning the body recovery methods at home was developed. The technology is based on a mobile application running under Android operating system, which implements functions of a virtual instructor, with the help of a 3D model. To analyze the results, a computer system FASEGRAPH® was used which automatically determines ordinary and original parameters of a single channel electrocardiogram as well as a modern fitness sensor Xiaomi Mi Band 2, which gives the opportunity to monitor sleep with the help of the built-in pulse meter.

Keywords: information technology, FASEGRAPH®, fitness sensor, resting breathing.

Introduction

Stress is one of the most common causes of human suffering, and excessive stress (distress) often leads to pathological conditions, in particular, to cardiovascular pathologies [1]. According to sociologists, almost 70% of Ukrainians are constantly in stress, and one third of the population is in a state of severe stress [2].

Another significant problem of the modern society – spine diseases, which also lead to severe consequences, in particular neurological disorders, hernia, osteochondrosis, arthritis [3] and even disability.

There is a great number of recovery techniques, the mastery of which reduces the negative effects of stress and improves the spine's conditions in the early stages of violations. Among such methods in the first place there is the method of resting breathing and the complexes of exercises of medi-

cal gymnastics. With the help of computer programmes [4] and video [5], which demonstrate such techniques, you can carry out the restoration of the body at home.

At the same time, most of the known computer programmes and videos provide only general recommendations for restorative techniques and demonstrate recovery exercises, without taking into account personal characteristics of the body such as age, sex, blood pressure, general fitness of the body, and so on. Therefore, the actual task is the creation of information technology (IT), which, with the help of a virtual electronic instructor, will allow to adapt the technique for a particular user and to assess the effectiveness of the organism restoration at home. Taking into account the fact that according to the rough estimates, almost 65% of Ukrainians use smartphones in their lives so it is expedient to implement such technology as a mobile application.

The purpose of the article is a creation of the integrated IT to restore the adaptive capacity of the body at home based on the mobile Android application to the smartphone.

Modern methods of the body recovery

One of the popular ways to reduce the negative effects of stress is to master the respiratory mediators, among which the most well-known are: diaphragmatic [6] and square breathing square, [7] techniques, respiration by the Buteyko method [8], meditative breath by the method of Norbekov [9], yogas respiration, Strelnikov's respiratory system [10] and Bulanova's respiratory system [11], rebaping [12], cholotropic breathing [13], respiratory gymnastics [14], and others.

It is clear that each of these techniques has its own characteristics and limitations. Therefore, the first natural question arises – which methodology should be used as the basis for the creation of the IT. To answer this question, we will take into account the following criteria:

- **popularity** – relative number of links to the methodology in searching system of the Internet;
- **contraindications** – the number of diseases, in the availability of which it is not recommended to apply the method;
- **accessibility** – simplicity of mastering the technique at home;
- **efficiency** – the correlation of positive or negative comments published by online users;
- **restrictions** – age or gender restrictions;
- **intensity** – the required number of repetitions of exercise to restore the body.

On the basis of the analysis of available literature sources, a table of binary relations (paired advantages according to the given criteria) of ten known methods of restorative respiration (alternatives) was constructed and by using Saati method [15] it was determined that diaphragmatic and square breathing techniques could be considered the most attractive for domestic consumption (Fig. 1) [16].

The second important trend in restorative techniques is the implementation of the special therapeutic exercises aimed at reducing back pain and

preventing the development of spinal column disease in the early stages. Such exercises are not complicated and can be done at home without additional facilities.

According to [17], the complex of exercises by the method of Sergei Bubnovsky (Fig. 2), which are done in a certain sequence on the recommendations of the doctor, provides treatment of initial dysfunctions of the musculoskeletal system and leads to a complete recovery of the body.

Also, therapeutic exercises according to Paul Bragg's method [18] (Fig. 3) are also popular, who, like many other experts, believes that “Spine is the key to health”.

Other methods of treatment were also popular, including V. Dikul's technique [19], which provides not only the training of the muscles of the back but also of the chest, abdomen and limbs.

It should be noted that a qualified instructor of a rehabilitation center usually adapts healing exercises to the individual characteristics of a particular patient. But in the modern world, people do not have much time to access medical facilities, and classes with a personal instructor at home are not available to every user.

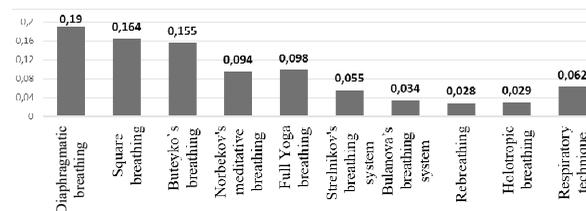


Fig. 1. Ranking of methods of restorative breathing by Saati method [16]

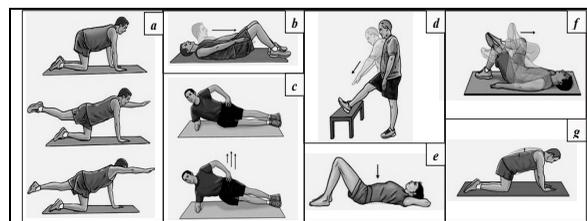


Fig. 2. Examples of exercises in the method of S. Bubnovsky [17]: *a* – lifting of the hand / foot from a position on all fours; *b* – partial twisting; *c* – side bar; *d* – hamstring stretch; *e* – pelvic inclinations; *f* – stretching of the gluteus muscles; *g* – cat and camel

It seemed like a way out of this situation is the restoration of the body at home with the use of available video films, in which a qualified instructor demonstrates the basic skills of these techniques. But the exercises that are shown in such films are aimed at the “average” user. In other words, if a user independently uses a video at home, then, unlike real lessons with a personal instructor, he is deprived of the opportunity to perform exercises with the required pace, range of movements and other important features, taking into account the individual peculiarities of his body.

At the same time, the development of computer technologies and methods of 3D modeling [20] allows today to create a “virtual” instructor who will demonstrate a therapeutic exercise adapted to the recommendations of a physician-reabistologist to a particular patient on a computer tablet (smartphone).

3D creation and animation technology

There are many techniques for character animation, most of which are used in the gaming industry [21]. However, there are almost no ready-made animations of physical exercises, as well as detailed animations of breathing. And also in the simulation of breathing, there is a number of obstacles, because the animation is not related to the human skeleton, but with the muscles. Therefore, to build a virtual instructor with realistic animation and the ability to control animation of movements, there is a need to create such a 3D model from scratch.

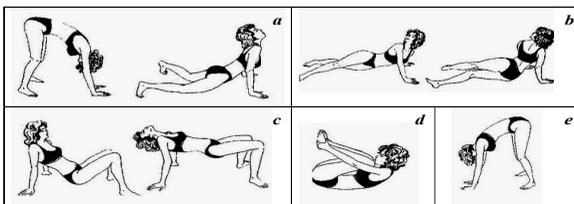


Fig. 3. Braga's Exercises for Muscle Training: *a* – the cervical spine; *b* – the thoracic spine; *c* – the muscle of the lumbar spine; *d* – the connection of the lumbar muscle with the buttocks; *e* – the connection of the femoral muscles with the femur

Let's consider first the simulation process of the 3D animation of the instructor, demonstrating the breathing exercise (Fig. 4). In the first stage (Fig. 4, *a*) in the 3Ds Max environment, we will develop a 3D model in the form of a set of polygons. This process begins with the selection of a template photo with two projections (frontal and sagittal) and the design of geometric shapes of different parts of the human body. Then carry out scaling and segmentation of these figures, adding sections and removing unnecessary faces to maintain the quadrangular structure of the polygons.

After completing all the parts, the smoothing of of the body of the model, by means of the programme 3Ds Max. To give the model more realistic look, an overlay of textures (Fig. 4, *b*) is used. In order to create a skin for a model, it is necessary to develop a scan, which allows solving the problem of how to apply a flat (two-dimensional) image to three-dimensional geometry.

Adobe Photoshop CS 6 was used to create the spreadsheet.

The development of the frame of the animation is to create a skeleton character (Fig. 4, *d*). For this purpose rinning is used – the process of preparing a character for animation, which includes creating and placing inside a three-dimensional model, virtual “skeleton” – a set of “bones” or “joints” and establishing a hierarchical relationship between them and others.

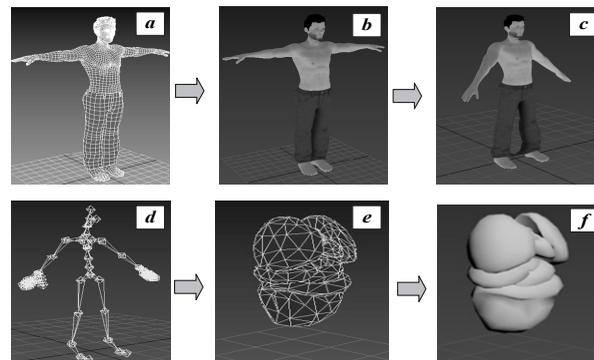


Fig. 4. The main stages of creating a “virtual instructor”: *a* – polygon representation of the 3D model; *b* – texture layout; *c* – animated model; *d* – sketch for animation; *e* – fragment of the chest skeleton; *f* – animated chest

After the rigging is the process of skinning, which consists of assigning links between the parts of the surface of the very figure that is animated. For example, it is necessary that the bone corresponding to the extreme phalanx of the finger affects only the desired group of vertices on the surface of the 3D animated shapes. That is, to change the position of this phalanx would not lead to bending the entire hand of the character.

The animation stage of the body part which bound to the skeleton consists of the following stages. We bring the objects of the scene to the original position (place our character in the original position before the animation) and set the slider animation timer to zero. Then we set the frequency and number of frames of the animation and activate the manual animation mode. Next, we move the slider to the native key animation frame, and set the required values of our parameters, that is, we return a certain segment of our model to the desired angle (Fig. 4, *c*), or move to another place, using attachment to the skeleton. In particular, when moving with a particular joint, the part of the body that is attached to it is moved in the skeleton (Fig. 4, *d*). After that, we set the animation key to fix the values of the settings. Smooth transition from one position to another between the key frames the 3Ds Max programme makes itself.

Since the creation of the animation of the thorax is not related to the skeleton, for a realistic picture, 3D models of internal organs, which are responsible only for the process of breathing (Fig. 4, *e, f*), are constructed. In this case, animation occurs by changing the size of the lungs and the diaphragm by moving the polygons. These organs then bind to the entire body, and when moving of the internal organs, the part of the human body that displaces them internally is displaced.

All of the above stages of simulation of the virtual instructor, which demonstrates the breathing exercise, were also used to simulate spine recovery technique (Fig. 5).

The final result is influenced by the detail of the image of each of the frames. It is important for each action to take into account the timing to

eliminate the problem of the absence of possible delays. To ensure smooth transition between frames, the programme application implements a special Auto Key mode that calculates point movements for each millisecond. Only the most visible transitions from one state to another are configured manually.

Structure of information technology

To solve this problem, IT was created (Fig. 6), which, with the help of dynamic 3D models of virtual instructors, provides the display and adjustment of processes for performing respiratory techniques and healing exercises for strengthening back muscles at home.

Virtual instructors are implemented on a mobile application running Android operating system. The mobile application allows you to demonstrate and adjust the parameters of the respiratory exercise (inspiratory duration, respiratory depression, exhalation, total time of the procedure), as well as the duration and number of approaches when performing muscle recovery exercises in the back.

In order to assess the effectiveness of the restoration of the body in the first stage, with the help of special devices, the initial rates of a particular patient are recorded. At the second stage, using a virtual instructor and individually selected pa-

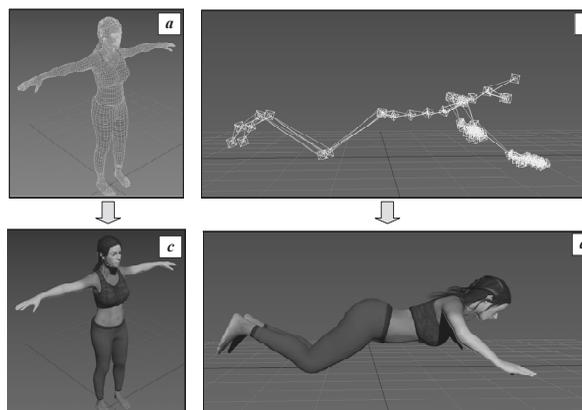


Fig. 5. The main stages of creating a “virtual instructor”: *a* – polygon representation of the 3D model; *b* – skeleton for animation; *c* – texture overlays; *d* – animated model

rameters, a restorative technique are carried out. The last step is to register and process the physiological status of a particular patient after a rehab and evaluate its effectiveness.

The examination of the effectiveness of respiratory techniques is carried out with the help of the domestic diagnostic complex **FASEGRAPH®**, which is based on a microprocessor sensor with finger-electrodes for the registration of a single-channel electrocardiogram (ECG) and a computer programme that provides automatic ECG-processing. The complex implements an innovative method of fasegraphy [22] and provides definition:

- averaged heart rate (HR) and traditional indicators of single-channel ECG – amplitude-time parameters of corresponding teeth, intervals and segments;
- original indicators of ECG in the phase space (symmetry index of the tooth T and its mean square deviation of the STD β_T), the diagnostic effectiveness of which is confirmed by the results of clinical trials [23];
- statistical and spectral parameters of heart rate variability (HRV).

The system consists of six scenes (menu, start of breathing technique, start of spine recovery technique, setting of parameters, review of instructions, description of the programme), depicted in the diagram (Fig. 7), with transitions between them.

When you open the programme, the main menu of the application is displayed (Fig. 8). To start the model of a virtual instructor, you must choose the breathing techniques, or spine recovery

techniques, with a window where you can start the model according to the parameters that were previously set. To change the settings, go to the “Options” item. The virtual instructor menu provides an opportunity to read the programme’s instructions and developer data.

Fig. 9 shows a sequence diagram for adjusting the parameters of the restorative technique. If the settings for breathing parameters are selected, the user can set parameters such as: breathing time, breathing, exhalation, overall duration of the procedure and type of breathing.

When choosing spine recovery technique you need to: select the level of training, for this you should pass the test, you can also change the time of the exercise, the total time of passing the technique and a brief review of each exercise.

Since it is known that with a back pain, usually a person’s sleep is disturbed; therefore, for assessing the effectiveness of the techniques for restor-

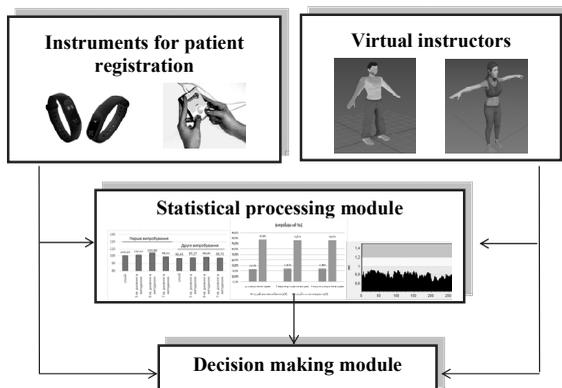


Fig. 6. Structure of information technology for the restoration of the organism

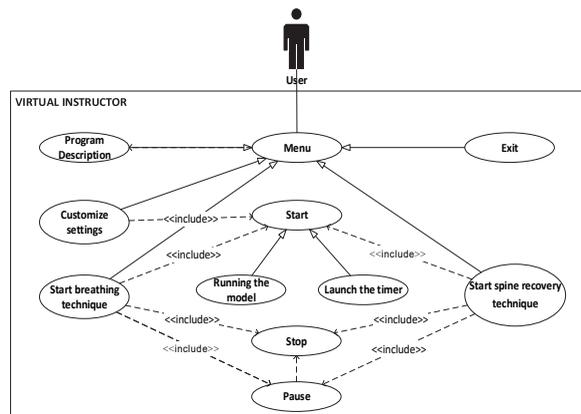


Fig. 7. Use-case IT chart

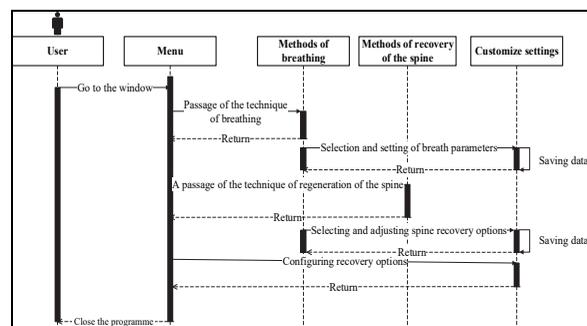


Fig. 8. UML sequence diagram of the programme

ing muscle back, it is suggested to use the Xiaomi My Band 2 fitness trainer (Fig. 10) with a built-in pulse meter.

Information about the user's sleep per week is read from the fitness tracker, namely:

- total sleep time, in particular, hours in which the user has fallen asleep and wakes up;
- duration of the deep sleep phase;
- duration of the fast sleep phase.

It is known [24] that a deep sleep phase is needed for the human body to restore physical functions. During this time there is the process of the cells and internal structures renewal, energy is restored, muscles grow, hormones are released. The norm of deep sleep among adults is in the range of 30 to 70% of the total duration. During the fast phase of sleep, work takes place at the level of the mental and emotional areas: the nerv-

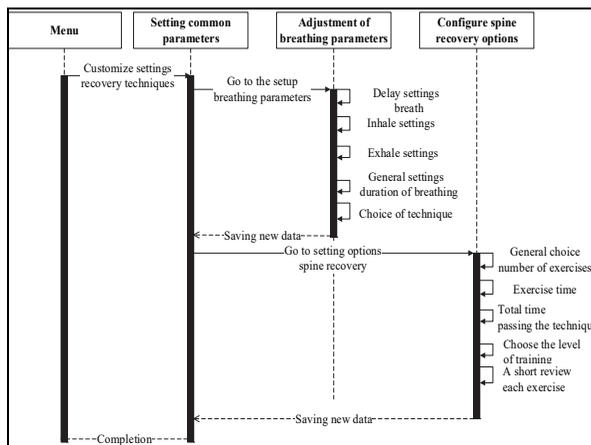


Fig. 9. UML sequence diagram for setting method parameters



Fig. 10. Tools for monitoring user's sleep: a – fitness tracker Xiaomi My Band 2; b – programme of monitoring of sleep

ous system is restored, information is processed, memory is tempered and other body structures are restored.

According to this, the dynamics of the slow and fast phases of sleep ratios carries important information about the functional state of the organism and can confirm or disprove the effectiveness of applying the method of recovery of the back muscles.

Practical results of the testing of the created IT

The study of the rehabilitation technique effectiveness was conducted in a group of 12 healthy volunteers at the age of 21–24. Compared the above ECG and HRV indices in the initial state and after conduction of restorative breathing using diaphragmatic or square breathing techniques. To do this, after setting up, the subject should breathe in synchrony with the virtual instructor for 5, 6 and 7 minutes at certain intervals of rest.

Visibility of the information provided by the FASEGRAPH® complex allowed to conduct not only quantitative but also qualitative assessment of changes in the functional state of the user based on

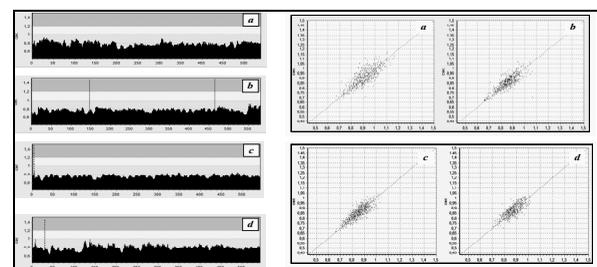
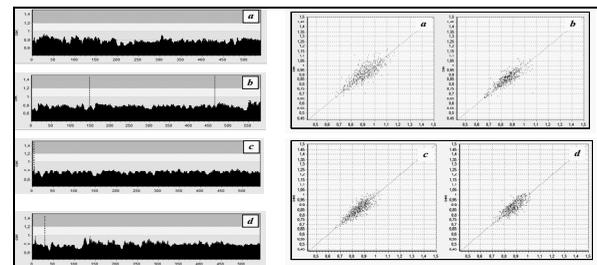


Fig. 11. Rhythmograms (left) and skaterograms (right) R – R – intervals: a – the initial state; b – 5 minutes breath; c – 6 minutes breath; d – 7 minutes breath

visual analysis of cognitive graphic images (rhythmograms, scherograms, spectrograms $R-R$ – intervals and phase trajectories of the ECG) that were observed during the implementation of the method of restoration of the breathing.

Fig. 11 shows cognitive graphic images that were observed at one of the subjects during the implementation of the technique. The tests showed that the majority of volunteers had a decrease in the size of the Poincare-Lorentz spot on the skaterogram -intervals with simultaneous positive dynamics of the voltage index of regulatory systems, which was automatically determined by the **FASEGRAPH**[®] complex according to the standard method [25].

FASEGRAPH[®] also allowed to confirm the weakening of the influence of parasympathetic activity and increase of sympathoadrenal activity based on the power balance analysis of the spectral components $R-R$ intervals in the region of the low (LF) and high (HF) frequencies [26].

Changes in the average ECG cycle shape were also observed (Fig. 12). More clearly, such changes manifested in the phase plane: with subjective complaints of the patient, an increase in the magnitude of the spread of phase trajectories was observed.

Practically, in all volunteer after conduction of restorative respiration, there was a positive dynamics of the original index β_T , which, according to the phasagraphy method, carries important diagnostic information about myocardial ischemia [24].

During a certain period (from 15 to 30 days) volunteers, with the help of the virtual instructor, independently were engaged in the method of restorative respiration at home. After that, a second test was carried out, again using the **FASEGRAPH**[®] complex, the ECG and HRF indices in the course of the implementation of the respiratory exercise were determined and the graphs of the percentage changes in relation to their values in the first test were built (Fig. 13).

As can be seen from Fig. 13 of the volunteer A, after the restoration of breathing procedures (in the second test), there was a decrease of HRV and β_T in comparison with the first test, which confirms the effectiveness of the exercises.

Volunteer B observed a further decrease in the indicator β_T with simultaneous increase of HRV. It should also be noted that during the first and sec-

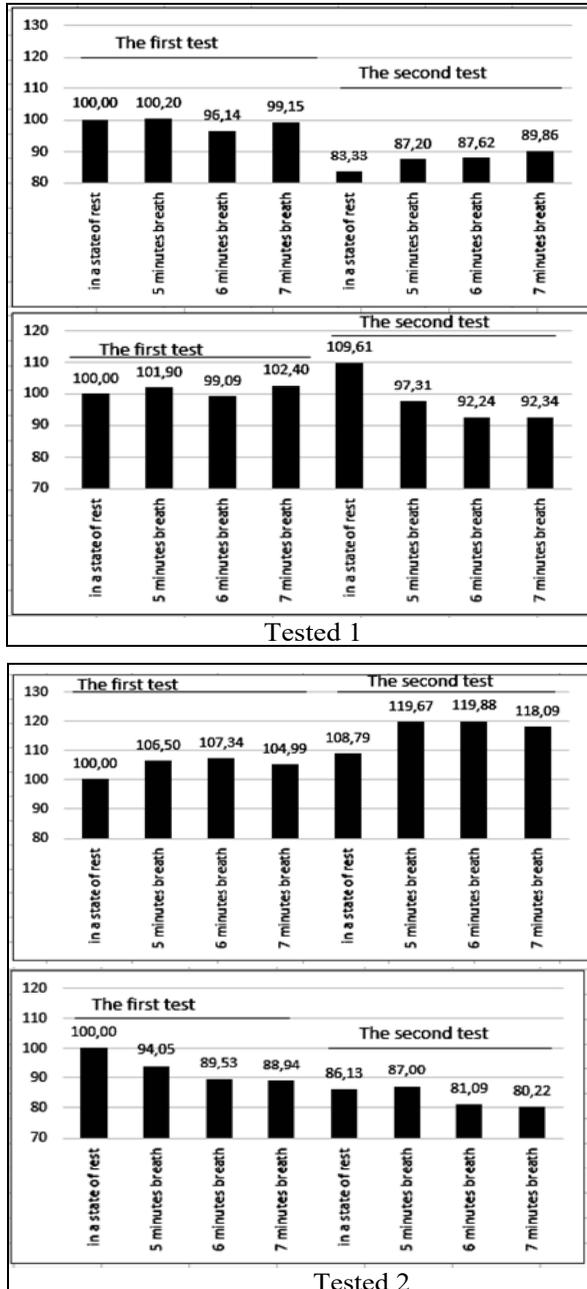


Fig. 13. Dynamics of heart rate (top) and indicator (below) for two subjects (volunteers)

ond exercises volunteer B observed a monotonous decrease in the indicator β_T in the process of respiratory load growth.

The multidirectional nature of adaptations of volunteer regulatory systems is likely to be related to the different levels of their fitness. It is clear that such an assumption can only be considered as a working hypothesis, which requires more in-depth study.

Similarly, a group of 8 healthy volunteers aged 18–40 conducted an assessment of the effectiveness of back muscles recovery methods. To do this, before training sessions with the fitness tracker *Xiomi My Band 2* during the week, we determined the averaged volunteer's sleep characteristics. Then, volunteers with the help of virtual instructors with individually adjusted parameters for two weeks were engaged in the method of recovery of the back. After completing the training, volunteers' sleeping characteristics were again determined and analysis of changes in the ratio of slow and fast volunteer sleep duration compared with the initial characteristics.

Fig. 14 illustrates the results of two volunteers sleep monitoring before and during training.

It is easy to see that both volunteers experienced a positive dynamics of sleep quality. At the same time, after two weeks of training in volunteer number 2, the deep sleep phase increased by almost 14 percent (from 24.37% to 38.29%), indicating a high efficiency of the restorative technique. Positive dynamics of sleep quality (extended deep sleep phase) was observed in all volunteers while undergoing a technique, together with simultaneous subjective sensation of general improvement of the body's condition.

It is clear that the first positive results of the testing of the created IT require a detailed study of pain on representative samples of observations to evaluate the statistical significance of the results obtained.

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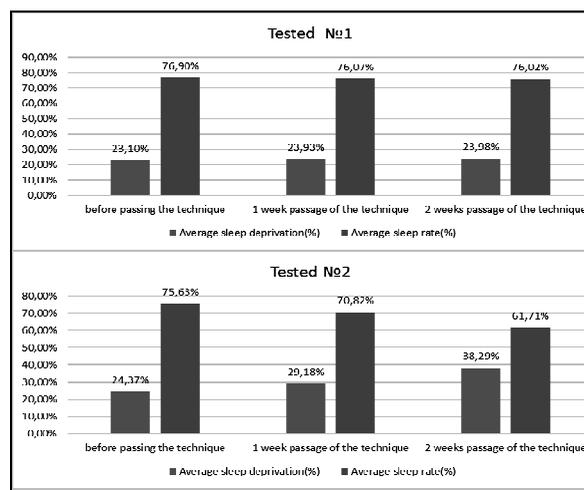


Fig. 14. Dynamics of indicators of deep and fast sleep of two subjects (volunteers)

Conclusion

The proposed IT, thanks to the visual presentation of the technique of restorative respiration and the technique of the spine recovery, by means of the created 3D model of the virtual instructor, allows to improve the quality of the recovery techniques training.

The use of the virtual instructors allows adapting the restorative technique to a particular user, taking into account his personal characteristics and recommendations of the physician-rehab.

Using a comparative analysis of ECG and HRV indices determined by the diagnostic complex **FASEGRAPH®** before and after the course of the breathing exercises, and the monitoring results of sleep monitoring determined by the fitness tracker *Xiomi My Band 2* before and during the course of therapeutic exercises to improve the spine, demonstrated the effectiveness of the proposed IT.

In the future, we intend to expand the functions of virtual instructors by improving 3D models and conduct an additional research to assess the statistical significance of the results.

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ІНФОРМАЦІЙНА ТЕХНОЛОГІЯ НАВЧАННЯ МЕТОДИКАМ ВІДНОВЛЕННЯ ОРГАНІЗМУ В ДОМАШНІХ УМОВАХ

Вступ. Існує велика кількість відновних методик, оволодіння якими забезпечує зменшення негативних наслідків стресу та поліпшення стану хребта на ранніх стадіях порушень. Освоїти методики можна в домашніх умовах за допомогою комп'ютерних програм та відео. Однак вони дають лише загальні рекомендації відновних методик та

демонструють відновні вправи, не враховуючи персональні характеристики організму. Тому актуальною задачею є створення інформаційної технології (ІТ), яка за допомогою віртуального електронного інструктора дозволить адаптувати методику під конкретного користувача та оцінити ефективність відновлення організму в домашніх умовах.

Мета статті – створення інтегрованої ІТ для відновлення адаптаційних можливостей організму в домашніх умовах на основі мобільного *Android*-додатку до смартфона.

Методи. Запропонована ІТ, яка за допомогою динамічних 3D-моделей віртуальних інструкторів та реалізованого мобільного додатку, забезпечує відображення та налаштування процесів виконання методик відновного дихання та лікувальних вправ зміцнення м'язів спини в домашніх умовах. Мобільний додаток дозволяє демонструвати та налаштовувати параметри дихальної вправи (тривалість вдиху, затримки дихання, видиху, загального часу виконання процедури), а також тривалість та кількість підходів при виконанні вправ відновлення м'язів спини.

Результат. За порівняльним аналізом показників ЕКГ та ВРС, визначених діагностичним комплексом ФАЗАГРАФ® до та після курсу дихальних вправ, та результатів моніторингу сну, визначених фітнес-трекером *Xiomi Mi Band 2* до та під час курсу лікувальних вправ для поліпшення стану хребта, продемонстровано ефективність запропонованої ІТ.

Висновок. Запропонована ІТ завдяки наочному поданню методики відновного дихання та техніки відновлення хребта за допомогою створеної 3D-моделі віртуального інструктора дозволяє підвищити якість навчання методики відновлення. Застосування віртуальних інструкторів дозволяє адаптувати відновну методику під конкретного користувача з урахуванням його особистих характеристик та рекомендацій лікаря-реабілітолога.

Ключові слова: інформаційна технологія, ФАЗАГРАФ®, фітнес-датчик, відновне дихання.

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ИНФОРМАЦИОННАЯ ТЕХНОЛОГИЯ ОБУЧЕНИЯ МЕТОДИКЕ ВОССТАНОВЛЕНИЯ ОРГАНИЗМА В ДОМАШНИХ УСЛОВИЯХ

Введение. В современном мире существуют разнообразные методики восстановления организма, обучение которым обеспечивает уменьшение негативных последствий стресса и улучшение состояния позвоночника на ранних стадиях патологий. Освоить такие методики в домашних условиях можно с помощью компьютерных программ и видео. Однако такие средства дают лишь общие рекомендации восстановительных методик и демонстрируют упражнения без учета индивидуальных характеристик организма. Поэтому актуальна задача – создание информационной технологии (ИТ), которая с помощью виртуального электронного инструктора позволит адаптировать методику под конкретного пользователя и оценить эффективность восстановления организма в домашних условиях.

Цель статьи – создать интегрированную ИТ для восстановления адаптационных возможностей организма в домашних условиях на основе мобильного *Android*-приложения к смартфону.

Методы. Предложенная ИТ с помощью динамических 3D-моделей виртуальных инструкторов обеспечивает отображение и настройку процессов выполнения методик восстановительного дыхания и лечебных упражнений укрепления мышц спины в домашних условиях. Мобильное приложение позволяет демонстрировать и настраивать параметры дыхательного упражнения (продолжительность вдоха, задержка дыхания, выдох и общее время выполнения процедуры), а также продолжительность и количество подходов при выполнении упражнений восстановления мышц спины.

Результат. Сравнительный анализ показателей ЭКГ и ВРС, определенных диагностическим комплексом ФАЗАГРАФ® до и после курса дыхательных упражнений, а также результатов мониторинга качества сна, определяемого фитнес-трекером *Xiomi Mi Band 2* до и во время курса лечебных упражнений для улучшения состояния позвоночника, продемонстрировал эффективность предложенной ИТ.

Вывод. Предложенная ИТ благодаря наглядному представлению методики восстановительного дыхания и техники восстановления позвоночника с помощью созданных 3D-моделей виртуальных инструкторов позволяет повысить качество обучения методикам восстановления организма. Использование виртуальных инструкторов позволяет адаптировать восстановительную методику под конкретного пользователя с учетом его индивидуальных характеристик и рекомендаций врача-реабілітолога.

Ключевые слова: информационная технология, ФАЗАГРАФ®, фитнес-датчик, восстановительное дыхание.