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The application of console games – exergames in cardiac rehabilitation: a pilot study

Zastosowanie interaktywnych gier konsolowych w rehabilitacji kardiologicznej: badanie pilotażowe

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Abstract

Introduction. Too many people avoid regular physical activity, and therefore various strategies are taken to increase their motivation. In recent years, exercising with the use of console games, i.e. exergames, has gained popularity.

Material & Methods. The study included patients referred for an early post-hospital inpatient rehabilitation. All subjects participated in endurance training on cycle ergometers and in fitness exercises (dynamic, stretching, coordination, balance) with elements of resistance training 5 times per week. In the test group, the rehabilitation program was complemented with training with ActivLife equipment. Training sessions took place every day, 5 times a week. They involved training program consisting of 7 exercises that develop motor abilities: coordination, strength and balance in the form of activities similar to traditional exercises – squats, lateral flexion, three-plane movements of the upper limbs and torso deflections in sagittal plane. Trainings lasted from 15 to 20 minutes.

Results. After rehabilitation significant improvement of exertion tolerance was observed in patients in both groups in the following tests: 6MWT [m] – test group: 369 vs 426, $p < 0.05$, control group: 341 vs 434, $p < 0.001$; test of strength of the muscles in the lower limbs [number of repetitions/30s] were: test group: 11.4 vs 13.6, $p < 0.001$, control group: 9.9 vs 13.1, $p < 0.001$ and in the Up&Go Test [s]: test group 7.8 vs 6.7, $p < 0.01$, control group 8.4 vs 7.3, $p < 0.01$.

Conclusions. Interactive console games are evaluated by cardiac patients as an attractive, safe, and useful method of exercising. Training with the use of the ActivLife equipment has proved to be as effective as traditional exercises.

Key words:

exergames, cardiac rehabilitation, cardiology, physiotherapy, exercise

Streszczenie

Wprowadzenie. Zbyt wiele osób unika regularnej aktywności fizycznej, dlatego podejmowane są różne strategie mające na celu zwiększenie ich motywacji. W ostatnich latach zyskały popularność ćwiczenia z wykorzystaniem gier konsolowych, tzw. exergames.

Cele pracy. Czy exergames są przydatne w rehabilitacji kardiologicznej? Jaki jest odbiór systemu ActivLife przez pacjentów? Czy można bezpiecznie wykorzystywać ActivLife z pacjentami kardiologicznymi?

Materiał i metodyka. W badaniu wzięli udział pacjenci skierowani na wczesną, poszpitalną rehabilitację stacjonarną. Wszyscy uczestnicy brali udział w treningu wytrzymałościowym na cykloergometrach oraz w ćwiczeniach fitness (dynamiczne, rozciąganie, koordynacja, równowaga) z elementami treningu oporowego 5 razy w tygodniu. W grupie testowej program rehabilitacyjny został uzupełniony o trening z wykorzystaniem sprzętu ActivLife. Treningi odbywały się codziennie, 5 razy w tygodniu. Obejmowały one program treningowy składający się z 7 ćwiczeń rozwijających zdolności motoryczne: koordynację, siłę i równowagę w formie aktywności podobnych do tradycyjnych ćwiczeń – przysiady, zgięcia boczne, ruchy w trzech płaszczyznach kończyn górnych oraz odchylenia tułowia w płaszczyźnie strzałkowej. Treningi trwały od 15 do 20 minut.

Wyniki. Po rehabilitacji zauważono znaczącą poprawę tolerancji wysiłku u pacjentów w obu grupach w następujących testach: 6MWT [m] – grupa testowa: 369 vs 426, $p < 0,05$, grupa kontrolna: 341 vs 434, $p < 0,001$; test siły mięśni kończyn dolnych (liczba powtórzeń / 30 s) wynosił: grupa testowa: 11,4 vs 13,6, $p < 0,001$, grupa kontrolna: 9,9 vs 13,1, $p < 0,001$ oraz w teście Up & Go [s]: grupa testowa 7,8 vs 6,7, $p < 0,01$, grupa kontrolna 8,4 vs 7,3, $p < 0,01$.

Wnioski. Interaktywne gry konsolowe są oceniane przez pacjentów z problemami kardiologicznymi jako atrakcyjna, bezpieczna i użyteczna metoda ćwiczeń. Trening z wykorzystaniem sprzętu ActivLife okazał się równie efektywny jak tradycyjne ćwiczenia.

Słowa kluczowe:

exergames, rehabilitacja kardiologiczna, fizjoterapia, ćwiczenia

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Introduction

Too many people avoid regular physical activity, and therefore various strategies are taken to increase their motivation. In recent years, exercising with the use of console games, i.e. exergames, has gained popularity. One of the assumptions of training in virtual reality is providing entertainment with the aim to promote physical activity. The notion of interactive console games (the term "exergames" stands for exercise games) was first introduced by Jeff Sinclair in 2007. The attempts to implement this idea date back to as early as the 1980s, i.e., the beginning of the commercialisation of computer games.

The first interactive game that received publicity was Dance Dance Revolution, released by Konami in 1998 [1]. Nevertheless, the concept that the camera should recognise the movements of an exercising person had to wait for the further development of optic technology. In 2004, Sony created the system called Eye Toy, which used a two-dimensional person detection to control the game. The first full-size console was Nintendo Wii (2006), in which the camera detected three-dimensional accelerations. A further development of that console allowed for the recognition of hand gestures, which has been used in the rehabilitation of people after stroke to this day [1].

Interactive console games require active physical participation of their users. They allow for an attractive combination of the process of rehabilitation with the tasks that are usually associated with pastimes. Many of the largest firms that manufacture consoles for games are involved in the production of the hardware and software that can be used in different areas of rehabilitation, such as neurology, cardiology, paediatrics, orthopaedics or preventive healthcare. The best-known brand names include PlayStation Move, Nintedo Wii and Microsoft Xbox Kinect [1]. Exergame systems are provided with a computer, game console, kinect camera and other equipment, such as a balance platform. The games are programmed in such a way as to mimic the physiological movements of a person in activities that increase muscle strength; improve balance, coordination and flexibility.

The purpose of this study was to compare the results of rehabilitation with the use of the ActivLife system in comparison to traditional exercises in patients with cardiovascular diseases undergoing early post-hospital rehabilitation.

Aim of the study

Is exergaming useful in cardiac rehabilitation?
What is the reception of the ActivLife system by patients?
Is ActivLife system safe for use with cardiac patients?

Matirial and methods

Research has complied with all relevant national regulations and institutional policies and has been approved by the authors' Regional Bioethics Commission with the number IK.NPIA.0021.42.1971/22 .

The study included patients referred for an early post-hospital inpatient rehabilitation. All subjects participated in endurance

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training on cycle ergometers and in general fitness exercises (dynamic, stretching, coordination, balance) with the elements of resistance training 5 times per week. In the test group, the rehabilitation programme was complemented with training with ActivLife equipment. Training sessions took place every day, 5 times a week for 4 weeks. They involved a training programme consisting of 7 exercises that develop various motor abilities: coordination, strength and balance in the form of activities similar to traditional exercises – squats, lateral flexion, three-plane movements of the upper limbs and torso deflections in the sagittal plane. Training sessions lasted from 15 to 20 minutes.
The proposed exercises were:

• kicking – alternating moves of lower limbs mimicking kicking a ball,
• ambulance (driving an ambulance) – side bends of the torso simulating changes of the driving lane by an ambulance overtaking cars on the street,
• aircraft (steering an aircraft) – torso bends in all planes,
• squats – performing a full squat with the use of the GymUp system,
• windows cleaning – movements of the upper limbs that imitate cleaning windows,
• pumping – movements that mimick inflating car tyres with a foot pump.

Figure 1. Presentation of the system

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The ActivLife equipment, which was used in the study, was provided with an Xbox® camera, laptop, a central unit with a big screen and a mobile platform with safety devices that reduce the risk of fall, and with the GymUp system. The ActivLife system was designed for use in rehabilitation through exergames, which gives a number of possibilities concerning the choice of exercises and customisation of the patient training. The majority of exercises were performed in a standing position; however, it is also possible to perform squats and exercises for abdomen muscles by lifting both lower limbs simultaneously. The ActivLife device allows for individual training through the selection of exercises (type, goal, number); focus on a particular body part; duration, speed and the number of stimuli.

Tasks for the patient are explained through demonstration on the screen and verbally by a physiotherapist. Movements that a patient makes are recognised by the camera and reflected on the screen in the form of the participation in a particular task, e.g. washing windows; which plays a significant role in physiotherapy, that of bio-feedback. After the completion of every exercise the achieved score is displayed on the screen.

Exercises in ActivLife are grouped with respect to the type of tasks which they may include: speed, movement precision, memory. Their main aim was to enhance patient's motor abilities, such as flexibility (range of movement in the joints), velocity, strength, endurance, coordination (learning new movements, balance), as well as the improvement in memory, concentration and logical thinking.

Figure 1. Presentation of the system

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Before and after rehabilitation all patients underwent a 6-Minute Walk Test (6MWT), Up&Go Test, and a Sit-to-Stand Test which evaluated the strength of the lower part of the body. The analysis in the test group involved the number of obtained points, percentage of the range of movement necessary to do the exercise properly, the speed of performed exercises in the subsequent training sessions with ActivLife. When the rehabilitation finished, a survey was conducted to evaluate attractiveness, safety and satisfaction with the exercises performed with the use of ActivLife.
Control group had been introduced to coordination and balance exercises accordingly to European and American Cardiac Society. What is more they underwent the standardized stage II rehabilitation consisting of cycloerometer endurance training, general conditioning training and breathing exercises.
Statistical analysis was performed with the use of SPSS 27.0 (IBM). Continuous variables were represented as means and standard deviations (for variables with a normal distribution) or median and Q1-Q3 (for variables with a distribution other than normal). Nominal variables were represented as absolute numbers and percentage of the group. Comparative analysis used difference tests, Kendall's coefficient of concordance test and Wilcoxon signed-rank test. The level of statistical significance was $p < 0.05$.

Results

The study was conducted in 43 patients (15 women and 28 men) aged from 41 to 84 years (mean 60.31 ± 11.75 years). Average body mass was 84.38 ± 19.00 kg, with an average BMI 28.15 ± 4.79 kg/m^2. The subjects were divided into two groups: a test group 17 patients (6 women and 11 men) and a control group – 26 patients (9 women and 17 men).

Table 1. Characteristics of tested groups

	Test group (ActivLife)	Control group	P
n	17	26	
Age [years]	59.91 ± 3.4	64.3 ± 15.4	ns
Left ventricular ejection fraction [%]	42	47	ns
Myocardial Infarction [n]	10	12	ns
Cardiac surgery [n]	3	6	ns
Heart failure [n]	8	8	ns

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After rehabilitation, a significant improvement of exertion tolerance was observed in patients in both groups in the following tests: 6MWT [m] – test group: 369 vs. 426, $p < 0.05$, control group: 341 vs. 434, $p < 0.001$; test of the strength of the muscles in the lower limbs [number of repetitions/30s] were: test group: 11.4 vs 13.6, $p < 0.001$, control group: 9.9 vs 13.1, $p < 0.001$ and in the Up & Go Test [s]: test group 7.8 vs. 6.7, $p < 0.01$, control group 8.4 vs. 7.3, $p < 0.01$. No significant differences were observed in the groups before and after rehabilitation.
After the completion of rehabilitation, a significant improvement ($p < 0.05$) was observed in particular motor tasks performed with the use of ActivLife (Figures 3, 4). In the questionnaire evaluating satisfaction with the proposed exercises 94.1% of respondents evaluated ActivLife as a very good method, 88% considered it as comfortable equipment, 100% of patients felt safe during rehabilitation, 94.2% indicated that interactive console games had been useful for the accomplishment of rehabilitation goals, and 59% of respondents considered ActivLife as a more attractive form of exercise in comparison with traditional training.

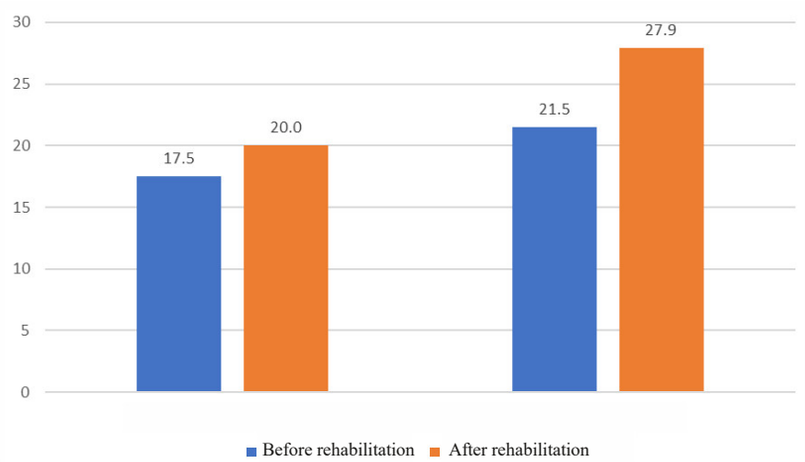

Figure 3. Scores as a percentage of the norm in games improving the speed of movements before and after rehabilitation (ActivLife)

Figure 4. Scores as a percentage of the norm in games improving the speed of movements before and after rehabilitation (ActivLife)

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Discussion

ActivLife is an exercise platform that was designed within the framework of the Horizon 2020 program. It integrates physical exercises with computer games in a way that is easy, accessible for everyone and independent of the age of participants. It allows for an interesting, involving rehabilitation, also of high intensity, but without the risk of fall. Thanks to a specially constructed protective platform movements are possible in all planes without the fear of a dangerous fall.

Barry et al. compared the results of exercises with the use of XBOX KinectTM and traditional gym workout in a group of 50 healthy adult subjects. Training with the XBOX system was reproduced in an identical way as in the gym. The programme consisted of 6 exercises: side jumps with a squat, fast changes of direction on command, boxing punches in place, lateral deflections on command, alternating kicks and start for sprint sideways on command. The subjects were assigned to groups randomly; each of them exercised for 30 minutes three times a week for 4 weeks. The analysed data included postural deviations with the use of KistlerTM force plate (postural sway), mean heart rate (HR), and the rate of perceived exertion (RPE). A greater improvement in body balance was observed with the exergame system than with traditional exercise. The obtained pulse rate and perceived exertion were lower in the case of exergames. The authors would like to emphasize a significantly better influence of interactive games on the level of motivation to exercise. The participants were evaluated with the Flow State Scale, which uses subjective opinions of the respondents, such as: immersion, commitment, clarity of instruction and the fear of exercising. Patients tested with the use of XBOX KinectTM were more motivated and involved in motor tasks, and the possibility to track and improve the obtained scores was more motivating for them [2]. Exergames are currently being used in physiotherapy in various groups of patients, also after stroke [3].

In another study, Esptepa et al. included participants with non-progressive brain injuries (ischaemic diseases), brain tumours and dystrophy, in a stable state, with motor deficiencies which were an indication for an intensive inpatient rehabilitation. Patients had a load of physical exertion that included activities aimed at improving balance or gait pattern. The selected system (Microsoft Kinect with three programmes of motor reeducation) offered the participants feedback in the form of an avatar (visualisation of movements in real time). Patients were additionally stimulated with sounds in the form of voice commands. The equipment summarised the course of the patient's therapeutic unit in the form of a quantitative assessment that contained data on the position of particular joints during the exercise. The database in the device enabled the therapist to compare the patient's results at different stages of rehabilitation, but also to create analyses for scientific purposes. The authors conclude that using their training programme may be particularly useful for the biomechanical analysis of patient's mobility and it is particularly well-suited for thorough periodic patient check-ups, based on an objective source of assessment [4].

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The other study conducted on patients after stroke, with exergames used as sports games, showed that the effort during this physical activity reached the values of 3.7 ± 0.6 MET – in the case of tennis and 4.1 ± 0.7 MET – in the case of boxing simulation. These values indicate the exertion of moderate intensity which is recommended by the American Heart Association for the maintenance of cardiovascular health and for cardiac rehabilitation [5]. Using interactive games in patients after stroke seems to be an effective way to help them regain their fitness. The long-term effect of using exergames in those patients is not evident; however, in the literature there are several publications confirming that the results lasted for at least two months. A long-term effect requires the extension of the period of monitoring the results of the participants.

A meta-analysis of 17 studies on the effectiveness of exergames showed their stimulating potential to enhance cognitive abilities, attention processing and visual-spatial functions of the patients. Patients with spina bifida, after stroke or with a spinal cord injury using exergames with moderate intensity considered them as effective and easy to learn and felt motivated to exercise.

As regards patients with the Parkinson's disease, complementing the therapy with a 12-week exercise program (30 minutes twice a week) with Nintendo contributed to the improvement in their control of equilibrium, and the enhancement of their anticipatory postural adjustment. The participants needed less time to perform the Up & Go Test and the number of repetitions in the lower body strength test increased. Console games may be used by the people from different age groups in various places (hospitals, nursing homes, schools) [6].

It was observed that in children with cerebral palsy who had participated in individualized training with exergames, cognitive functions improved through the increase of the level of attention and concentration. Another study performed in the same group of patients revealed that a 6-day training with the equipment using virtual reality may effectively influence the functions and strength of an inactive upper limb in children with hemiplegia [7].

The publication which summarized 6 studies concerning patients after cardiac surgery analyzed parameters included the exercise test with the use of 6MWT, the VAS scale to evaluate postoperative pain and the participation in the program of comprehensive cardiac rehabilitation. Instead of traditional exercises patients were provided with training with the use of various exergame programs. The control group was selected from a different study. The matching study had the same duration; yet, without the use of interactive console games. It was observed that the participants improved in terms of selective attention span and the ability to solve problems, the waist/hips ratio; the severity of postoperative pain decreased, functioning and distance in 6MWT improved. The participants more often reached the recommended value of the training heart rate, obtained higher values of VO_2max, MET and VO_2 values in the anaerobic threshold. While using a cycle ergometer they made larger distances, cycled longer and had higher loads. Despite this, the authors emphasized that the results were comparable to those obtained by a control group that had exercised in a traditional way [8].

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Another study of 605 eligible participants with heart failure investigated the influence of training with the use of console games at home on efficiency and motivation to exercise. The test group was equipped with virtual reality equipment and instructed on the method and frequency of exercises. Within the 3-month training the participants were contacted four times in order to assess their progress and clarify the issues that might have arisen. Patients from the control group were given standard recommendations concerning physical activity at home and over a period of three months four telephone calls were made to motivate them. After the completion of training sessions, no differences were observed between the test group and the control group in the distance covered in 6MWT. The 6MWT was conducted according to the procedure recommended by the American Thoracic Society, i.e. in the same way as the tests performed at the Department of Coronary Artery Disease and Cardiac Rehabilitation in Warsaw. In this study, 100% patients assessed ActivLife as safe, and the 6MWT results improved significantly (359 m vs. 434 m) [9].

Another group that benefits from training with the use of exergames are geriatric patients. However, as the society is ageing, increasingly more attention should be devoted to the introduction of the elderly to new methods in physiotherapy. Wuest et al. included 16 geriatric patients (aged > 64) in the study in order to conduct a series of balance training sessions with the use of exergames. The exercise programme consisted of 5 games with the purpose to train equilibrium and coordination, performed 3 times per week for 12 weeks. A single session lasted 30 minutes. The whole training was recorded by the platform and then analysed. For the evaluation of the effects of the training, the Borg Scale and the Up & Go Test were used. The results were divided into several categories: acceptance of training technology, commitment and test results. Improvement was obtained in almost all the parameters. The exercise programme with the use of the console seems to be a good alternative, also for the elderly, who become easily accustomed to a new type of activity. The participants paid particular attention to the fact that they improved their score from the previous session. They considered this as a factor with a profound impact on their motivation to exercise [10]. Nightingale et al. tested a group of 51 seniors (over 65 years old) who participated in a randomised trial comparing the Up & Go Test with the photoelectric balance test. The comparison showed a strong correlation between the results, suggesting that the Up&Go is a useful tool to assess balance of geriatric patients. In this study, one of the components of the patients' assessment was the Up & Go Test, in which after the completion of rehabilitation the patients achieved a significant improvement [11].

Rebsamen et al. conducted a study on 12 elderly participants who had not been physically active before. They took part in a 4-week endurance training of the HIIT type on the Senso equipment, used for exergames. The results of exercise tests conducted after the programme considerably improved in comparison to baseline results. In the vast majority of training sessions, the participants reached a forecasted limit of the training heart rate and the training time. The HIIT training with the use of virtual reality proved to be safe and effective.

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Satisfaction of the participants and the pleasure of exercising were rated by the respondents at a very high level, similarly to the results obtained in this study: 94.1% of respondents rated ActivLife as very good; 88% of respondents stated it was comfortable or very comfortable; 100% of respondents considered it as safe; 94,2% of respondents evaluated it as effective in reaching projected rehabilitation goals, and 59% of respondents considered it to be a more attractive training form than standard exercises [12]. Exergames application is increasing in the rehabilitation of patients with various diseases. The available scientific sources have testified to their effectiveness, both in terms of physical fitness, exercise tolerance, as with reference to cognitive abilities, attention processing and visual-spatial functions. Exergames were considered as safe and doable by patients in different countries, irrespective of the climate and healthcare system. In the present study we evaluated this method in cardiological patients which may be new option to increase effectiveness, attractiveness and motivation of the rehabilitation.

Conclusion

Interactive console games are evaluated by cardiac patients as an attractive, safe, and useful method of exercising. Training with the use of the ActivLife equipment has proved to be as effective as traditional exercises. The ActivLife equipment is safe and useful in cardiac rehabilitation and may be used in various settings.

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