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RESEARCH ARTICLE

THE ROLE OF TECHNOLOGY IN PERFORMING PHYSICAL ACTIVITY IN REHABILITATION PROGRAMS FOR PATIENTS WITH CARDIOVASCULAR DISEASES

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ABSTRACT

This research aimed to investigate the results of a kinetotherapy program carried out through a virtual assistant and monitored by wearables. The study includes a group of 10 patients with recomendation to enroll in a cardiovascular rehabilitation program. The investigation was carried out at the clinical Emergency Hospital 'Bagdasar-Arseni' between October 2020 and June 2021. The patient enrollment process was dificult in the current epidemiological context. Patients were initially evaluated using the cardiopulmonary effort test to determine if they have contraindications for effort and monitored throughout the ambulatory inhospital physiotherapy sessions (EKG, blood pressure, heart frequency, oxygen saturation). At the end of the recovery sessions another cardiopulmonary test was performed to see the evolution of patient effort. Rehabilitation sessions included physical exercises using digital games / „serious-games" and progressive resistance exercises. Vital parameters (blood pressure, ventricular alura, oxygen saturation), weight excess, effort tolerance level have improved. On the first day of kinetotherapy, the mean systolic blood pressure was 138 mmHg and the mean diastolic pressure of 83 mmHg compared to the last day the patients attended the recovery session when the mean systolic blood pressure dropped to 120 mmHg, and the diastolic mean dropped to 73 mmHg. As for heart rate, an improvement in rest values was observed, that demonstrates an increase in tolerance to effort and a reduction in deconditioning. The data obtained from active participation in physiotherapy programs show a considerable improvement in the effort capacity, functional independence and quality of life of patients.

Keywords: robotic surgery, TME, rectal cancer

INTRODUCTION

Cardiovascular disease remains the leading cause of death and disability worldwide, with around 1.7 million deaths and 37% of all deaths in European Union (EU) in 2017 [1,2]. A detailed analysis of the data shows that physical exercise has a considerable impact on prevention and improvement of cardiovascular diseases and mortality [3]. Recent data suggest that cardiorespiratory fitness (CRF) plays an important role in reducing mortality caused by cardiovascular diseases through acute myocardial infarction, hypertension, atrial fibrillation, heart failure, stroke. The cardiorespiratory fitness (CRF) prognostic value has been demonstrated in a variety of patient populations and cardiovascular diseases. Thus, a higher CRF is linked to prolonged life expectancy and a decrease in the incidence of cardiovascular diseases and other conditions [4]. The primary response of the cardiovascular system to physical exercise is the increase in heart rate (HR) caused by the domination of sympathetic tonus [5]. Heart rate increases linearly to

effort intensity, and a lower HR during physical activity allows an enhanced left ventricular fill with an increased end diastolic volume, which will eventually result in a higher stroke volume [6]. The most important functional adaptation of aerobic physical activity is the improvement of cardiac output due to increased contractility and blood volume, which allows better ventricular filling [6].

Recently, it became a subject of interest in recovery medicine the use of "serious games" integrated in the complex structure of virtual assistants. Virtual assistants come in many forms, from simple smartphone applications to complex deep learning systems, providing patients with remote moral and medical support. If they are to be widely implemented digital games installed on various electronic devices designed for educational and health improvement purposes, , will optimize the medical and social treatment costs of cardiovascular patients. [7]. A specific type of serious games is 'exergames'. These types of games are promising for patients with cardiovascular conditions, as they lead to an improvement in effort capacity/tolerance and energy costs [7]. Using "serious games" in cardiac rehabilitation targets the same goals of the classic kinetotherapy program, as it prevents muscle atrophy through exercises of strength and resistance depending on the selected game, improves coordination through specific games and determines long-term adherence due to curiosity, motivational design, and the degree of patient interaction with the system provided. This approach has the possibility to change overall how patients engage in the physical exercises required by the cardiac recovery programs [7]. At the moment, such a virtual assistant is under development, through funding of the European Union's Horizon 2020 Research and Innovation Programme. The virtual coaching activities for rehabilitation in elderly (vCARE) project has the overall objective to support the recovery of active and independent life at home. In the project development are currently involved twelve partners from seven European countries, together carrying out a multidisciplinary consortium of researchers, healthcare providers and industry experts. This product is designed and tested for patients diagnosed with stroke, Parkinson's disease, heart failure and ischemic heart disease, divided among the healthcare providers participating in the project [https://vcare-project.eu/project/objectives/].

Remote cardiac rehabilitation through virtual assistants, although promising, presents little data on efficacy in the current literature. Our study aims to investigate the results of a virtual assistant kinetotherapy program.

MATERIALS AND METHODS

The selective criterion of inclusion was the cause of hospitalization. Patients presenting with ischemic heart disease and NYHA II-III class chronic heart failure(CHF) were selected. Patients' enrollment in the study was voluntary, after a detailed presentation of the study design. All participants were informed about their right to privacy and about the private storage and use of their data. The study conducted did not present any potential psychological, social, physical, or legal harm to patients. An ethical approval has been obtained from the Ethical Commission of the University of Medicine and Pharmacy Carol Davila. A total of 10 patients, 7 men and 3 women, aged 24–75 years old, agreed to participate in the study and signed a comprehensive informed consent. The exclusion criteria were the following: unstable angina; systolic resting blood pressure: 200 mmHg and diastolic: 110 mmHg; uncontrolled arrhythmias; uncontrolled atrial tachycardia; recent pulmonary thromboembolism; motor disabilities; phlebitis; age under 18 years old.
Before any kinetotherapy program, cardiological workup was carried out to determine the functional level of the patient in order to achieve realistic goals, as well as to develop the recovery therapeutic plan. In addition, all patients were subjected to a cardiological evaluation, a cardiopulmonary effort test that set the targeted heart rates (THR).

0	1	2	3	4	5	6
Rest	Very Easy	Easy	Moderate	Difficult	Hard	

7	8	9	10
Very Hard		Very, Very Hard	Maximal Effort

Table 1 - Borg modified scale for perceived exertion

The target heart rate (THR) has been calculated for each patient included in the study from the results of the cardiopulmonary effort test and was progressively changed to the effort tolerance of each patient. Patients were initially evaluated using the cardiopulmonary effort test to determine if they have contraindications for effort and monitored throughout the physiotherapy sessions (EKG, blood pressure, ventricular allure, oxygen saturation). At the end of the rehabilitation sessions another cardiopulmonary test was performed to see the evolution of patient effort.
Using the Borg modified scale for perceived exertion (Table 1) we identified the level of physical exertion

that the patient experienced in the cardiovascular rehabilitation program. Physiotherapy sessions have been scheduled at a frequency of 3 times per week for the patients included in the present study.

In the cardiovascular rehabilitation sessions, the patients interacted with the system through the pre-established pathways. The system provides the patient with multiple pathways: daily motor activity, aerobic physical activity, resistance training ("serious games"), vital stats control, weight control, smoking cessation activity, E-learning, medication intake support and anxiety and depression reduction. Patients were monitored using a Smart Band for heart rate measurements during the physical activity through the cardio games packages (Figure 1).

Figure 1 - One of the patients during cardio games packages

Other electronic devices used for patients' monitoring are: Beurer BM85 for blood pressure, Xiaomi scale for body weight and a pulse oximeter for oxygen saturation. Using TV sensor Orbbec – Astra Pro 2018R3 and H96 – Max H2 the games could be played by the patients enrolled in the study. The interaction with the avatar was possible using a Lenovo Yoga Smart Tablet.

The games were modified by the medical staff (cardiologist and kinetotherapist) in order to adapt them to the needs of the cardiological patient and create a tailored program. Games' personalization was possible using an electronic professional portal and the gamification platform where only the medical staff had access. In Figure 2 is shown the variety of the games for our patients.

The Professional portal was used for patients' enrolment and needed private information such as name, date of birth, email address. The gamification platform was used for personalization of the „serious-games" and the possibility of adaptation to the patients' heart rate during the games.

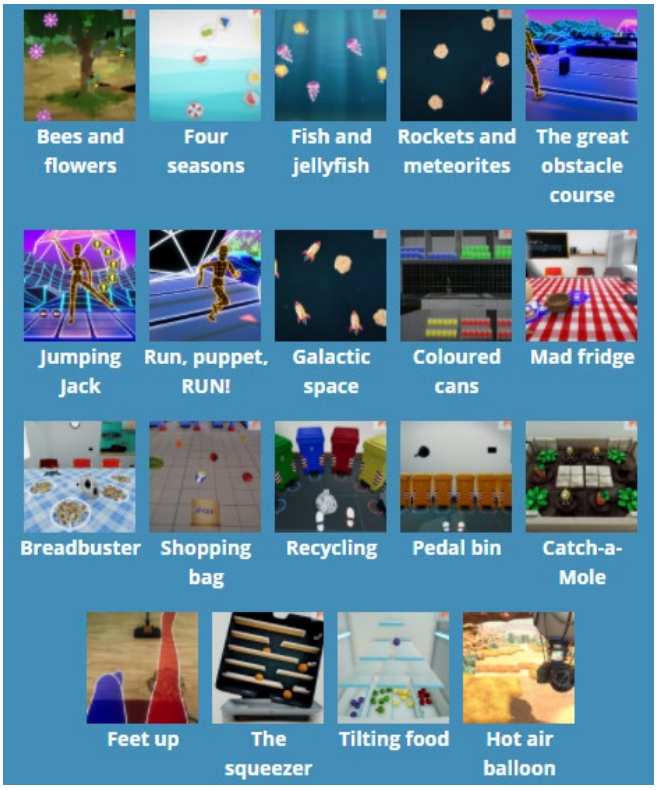

Figure 2 - Games available on the Rehability platform

Figure 3 - Notification about the scheduled activity

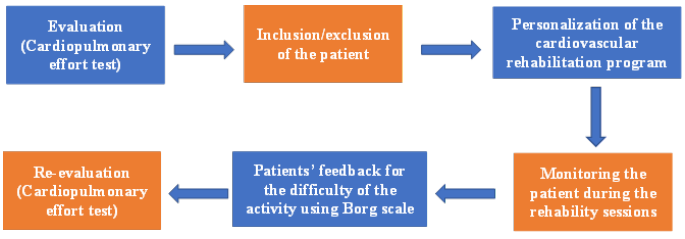

Figure 4 - Steps involved in the cardiovascular rehabilitation program

After the profiles were created and the parameters of the games were selected, the patients were able to choose the time of the day when they would like to perform the activity. The avatar application would notify the patients about the

scheduled activity (Figure 3), and they could either accept, refuse or post-pone the cardio games packages.

For each "serious-games" session, the application recorded the results obtained for each game and an average of each game for multiple sessions. This made possible to see which activity is more difficult for the patient to perform, as well as following a progress. The whole process of the cardiovascular rehabilitation programs is illustrated in Figure 4.

RESULTS

The study group has 10 patients, 7 men and 3 women. The small sample size of the study group is due to the COVID-19 pandemic. The access of the patients in the hospital was limited because the hospital was dedicated to COVID-19 patients.

In terms of cardiovascular risk factors, the enrolled patients have a minimum age value of 24 years old, a maximum age value of 75 years old, with a mean value of 53,9 years old and a standard deviation of 16,8. An increased body mass index is found in 9 out of 10 patients, with a maximum value of 41,36 kg/m², corresponding to morbid obesity. High blood pressure is found in 4 out of 10 patients. Dyslipidemia is another risk factor in our study and is present in 9 out of 10 patients. Diabetes Mellitus Type 2 is also present but only in 3 out of 10 patients (Table 2).

Before the enrolment of the patients in the study we tested their effort capacity to set the targeted heart rate and adapt the physical training activities to their needs and effort tolerance. In Figure 5 is a graphical representation of patients' heart rate at the first cardiopulmonary effort test (blue) and at the last effort test, after the cardiovascular rehabilitation program (orange), at the intensity of 100W. An improvement is highlighted in the decreasing of the heart rate for the initial and the last cardiopulmonary effort testing.

Patient No.	Age	Sex	BMI kg/m²	Smoker Status	Arterial Hypertension	Diabetes Mellitus Type 2	Dyslipidemia
1	44	M	23,15	Yes	No	No	No
2	35	M	29,3	Yes	No	No	Yes
3	72	F	30,49	No	No	Yes	Yes
4	65	M	41,36	Yes	Yes (Grade 1)	Yes	Yes
5	75	M	25,69	No	No	No	Yes
6	24	M	25,56	Yes	No	No	Yes
7	49	M	26,54	No	Yes (Grade 1)	No	Yes
8	55	F	29,69	Yes	Yes (Grade 1)	No	Yes
9	50	M	28,33	Yes	Yes (Grade 1)	No	Yes
10	70	F	29,03	Yes	No	Yes	Yes

Table 2 - Cardiovascular risk factors of enrolled patients

Patient No.	Initial Weight	Final Weight	Initial blood pressure	Final blood pressure	Initial oxygen saturation	Final oxygen saturation
1	75 kg	72 kg	130/90 mmHg	110/80 mmHg	96	98
2	81 kg	75 kg	130/80 mmHg	120/70 mmHg	94	98
3	82 kg	75 kg	130/70 mmHg	110/70 mmHg	94	97
4	137 kg	133 kg	140/80 mmHg	120/70 mmHg	93	96
5	76 kg	78 kg	130/80 mmHg	120/80 mmHg	96	98
6	63 kg	63 kg	140/90 mmHg	120/60 mmHg	95	98
7	86 kg	81 kg	150/90 mmHg	130/70 mmHg	97	99
8	76 kg	72 kg	140/80 mmHg	120/80 mmHg	95	99
9	98 kg	92 kg	150/90 mmHg	130/70 mmHg	95	98
10	80 kg	76 kg	140/80 mmHg	120/80 mmHg	93	97

Table 3 - Evolution of cardiovascular parameters and body weight during rehabilitation sessions

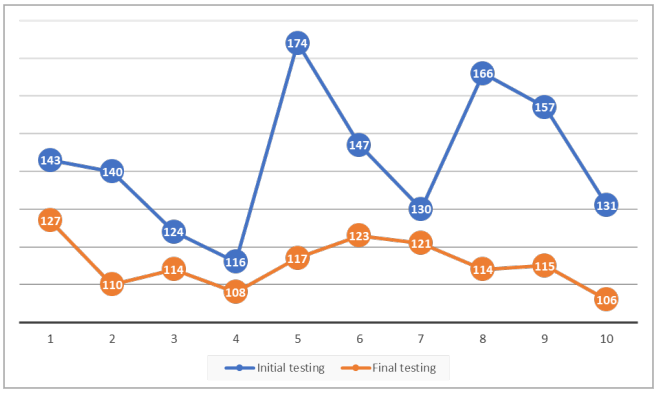

Figure 5 - Heart rate variation during initial and final cardiopulmonary effort testing (Reference: 100W)

In terms of high blood pressure, the values measured on the first day of cardiovascular rehabilitation program were higher than the values measured on the last day of the rehabilitation program. The mean value for the initial sistolic blood pressure, measured on the first day of cardiovascular rehabilitation program, is 138 mmHg and 83 mmHg for the diastolic blood pressure. On the last day of the kinetotherapy program, the mean value for the sistolic blood pressure was 120 mmHg and 73 mmHg for diastolic blood pressure. The oxygen saturation and body weight improved during the sessions (Table 3)

Patient No.	Resting heart rate on day 1	Resting heart rate on final day	Training heart rate on day 1	Training heart rate on final day
1	110	95	134	124
2	98	82	131	116
3	91	75	110	100
4	100	85	115	103
5	100	84	123	108
6	94	85	131	116
7	89	72	114	107
8	90	78	131	120
9	93	74	129	115
10	90	78	123	108

Table 4 - Evolution of resting and training heart rate during rehabilitation sessions

Questions	Patients									
	1	2	3	4	5	6	7	8	9	10
On a scale from 1 (very easy) to 7 (very difficult) select the complexity of the system.	4	6	4	2	7	5	7	3	3	2
Could the virtual coach replace a real person?	No	No	No	Yes	No	No	No	Yes	Yes	Yes
Would you prefer to interact with the virtual coach instead of a real person in cardiac rehabilitation programs?	No	No	No	Yes	No	No	No	Yes	Yes	Yes
On a scale from 1 to 10 (1-4: acceptable; 5-7: I liked it a little; 8-10: I liked it a lot) rate the cardio rehability sessions	8	8	10	8	8	5	9	2	10	9
Would you adapt the system at home?	Yes	Yes	Yes	Yes	No	Yes	No	Yes	Yes	Yes
What could be your limitations regarding the system?	No limitation	Complexity	No limitation		Internet		Complexity	No limitation		
What's your opinion about the integration of technology for the cardio rehability programs?	It's interesting. It will increase the adherence to the rehabilitation programs. It's innovative. It's useful for cardiac rehabilitation.									

Table 5 - Patients' appreciation / satisfaction regarding the provided system

As for the resting heart rate and training heart rate we observed an improvement between the first day and the last day of kinetotherapy. The mean value for the resting heart rate on day one is 95,5 and for the last day of kinetotherapy session is 80,8. We observed an improvement in the training heart rate during the rehabilitation program, calculating a mean value of 124 on day 1 and 112 on the final day (Table 4).

We created an appreciation / satisfaction questionnaire to be responded by patients after their interaction with the provided system. The answers are shown in Table 5.

DISCUSSION

The main purpose of this study was to evaluate the effectiveness of remote cardiac rehabilitation through virtual assistants as well as the opinion of patients on the method novelty.

Over the past decade, there has been an emphasis on developing a virtual cardiac recovery mode, using many technologies either uniquely or in combination, such as: Internet-related websites, smart phone applications, telemonitoring and even virtual reality features [8].

In the study conducted by Lear S., the applications installed on the smartphone were used to augment traditional cardiac rehabilitation and improve the results. In randomized clinical trials, applications with functions such as sustained physical activity monitoring, recommendations and information on diet and body composition associated with educational resources have achieved satisfactory results by improving adherence to cardiac recovery programs, body weight management through weight decrease as well as increasing tolerance to effort and improving mental status [8]. These smart application features have resulted in better results than traditional cardiac rehabilitation. In this study, through the results obtained, 8 out of 10 patients had a weighted decrease compared to the first kinetotherapy session [8].

However, the study conducted by Lear S., imposes as a limit the old age of some patients diagnosed with cardiovascular disease and requiring a cardiovascular rehabilitation program. It claims that patients over 65 years of age, although they have the possibility of an internet connection, they do not want to go beyond their daily routine to access some sites out of need and check mail to join a virtual recovery program [8]. In our study, only 2 out of 8 patients expressed their disagreement with the implementation of the virtual rehabilitation system at home. 8 patients of 10 want to implement the system at home and consider this treatment approach to be innovative, useful and to maintain long-term adherence through visual stimuli (the games through which the patient performs physical training; educational e-learning sessions on various topics; notifications that remind patients about medication, physical activity, the importance of hydration and a healthy diet)

A meta-analysis of 27 studies conducted by Gandhi S, Chen S, Hong L, et al. discovered that using mobile applications for virtual cardiac rehabilitation has led to an increase in patients' adherence to medication. This meta-analysis also found an improvement in patients' risk factors and healthy lifestyle recommendations [9].

With the help of a meta-analysis of 12 studies (1938 participants) carried out by Taylor R.S. et al., a comparison was made between the rehabilitation program carried out in the hospital and the one carried out at the patient's home. The results of the meta-analysis show that there were no differences between the cardiac rehabilitation in the physiotherapy room and the rehabilitation in the patient's home, both leading to beneficial changes in the cardiovascular risk factors [10].

CONCLUSIONS

This study shows the potential of a virtual coach to support remote cardiovascular rehabilitation programs and monitoring. The system represents the opportunity of medical services at patients' home, thus ensuring the secondary prevention of cardiovascular disease, with the provision of medical services in less accessible areas. The large-scale implementation of these services would benefit not only patients but also healthcare systems by reducing the medical costs required for in-person rehabilitation therapies.

LIMITATIONS

Our study presents some limitations that should be mentioned. The study sample was small, with a prevalence of male patients, consequently it does not provide an adequate characterization of the average Romanian patient.

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