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ORIGINAL ARTICLE

Home-based Virtual Reality Exercise Program During the Maintenance Stage of Cardiac Rehabilitation: A Randomized Controlled Trial

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Abstract

Background: Home-based virtual reality technology may become an alternative to cardiac rehabilitation.

Objectives: To evaluate the effects of a specific, home-based exercise program, performed either through a virtual reality (*Kinect*) or a conventional format (booklet) in the maintenance stage of cardiac rehabilitation for six months on functional muscle strength of the lower limbs, physical activity and exercise tolerance.

Methodology: This is a randomized clinical trial (*ClinicalTrials.gov* — NCT02753829) with individuals with coronary artery disease from a hospital in Porto, Portugal, randomly allocated to an experimental group "1" (EG1; n = 11), submitted to a virtual reality exercise program (Kinect); an experimental group "2" (EG2; n = 11), submitted to an exercise program described in a booklet (conventional format); or a control group (CG) (n=11), submitted to routine care. Parameters of functional muscle strength of the lower limbs (sit-to-stand test), physical activity (accelerometer) and exercise tolerance (stress test) were assessed and compared between the groups. Descriptive and inferential statistics were applied, with 95% with a significance level of 0.05.

Results: Significant improvements in functional muscle strength of the lower limbs were observed in EG1 compared to EG2, at three months (19.5 ± 7.7 *versus* 11.9 ± 4.7, p = 0.042), and at six months (23.0 ± 7.7 *versus* 14.6 ± 4.6, p = 0.027) of intervention.

Conclusions: The program did not demonstrate superior results, in relation to the control group and among the different formats, in physical activity and effort tolerance. In relation to the functional muscle strength of the lower limbs, the virtual reality format showed significantly better results when compared to the conventional format only.

Keywords: Technology; coronary disease; exercise; cardiac rehabilitation.

Introduction

In Portugal, cardiovascular diseases (CVD), including coronary artery disease (CAD), are the main causes of mortality and morbidity. For this reason, cardiac rehabilitation (CR) programs have been developed to promote a faster recovery of the patients.[1] In cardiac patients, there is a marked reduction in exercise tolerance, which contributes to a sedentary lifestyle, and CR programs have been associated with an increase in both exercise and functional capacity.[2]

CR is divided into three stages; the final stage is the maintenance phase,[3] aimed at maintaining long term capabilities and healthy behaviors developed in the training stage, focusing on patient self-regulation.[3]

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Avila et al.,[4] Ramadi et al.,[5] and Taylor et al.[6] concluded that home-based CR programs have nearly the same positive impact on several psychosocial and hemodynamic outcomes as conventional programs conducted in a hospital. Home-based CR was designed to improve the access to CR, overcoming theoretical, physical, and logistic barriers.[7]

According to Humphrey, Guazzi, and Niebauer,[8] the low adherence rates to CR are one of the many challenges and opportunities for future studies in Europe, together with the evaluation of its long-term impacts on CVD. The importance of exploring alternatives for the implementation of these programs, such as the home-based environment and the use of new technologies, is clear. Nevertheless, there are still few studies, with the Portuguese population, on the long-term effects of CR programs,[1] and the potential benefits of an exercise program implemented during the maintenance stage of a home-based CR program, not only for maintaining but also for achieving a more active and healthier life.

In addition, there is a pressing need for further studies regarding new CR alternatives, including virtual reality. Virtual reality can be implemented in several ways, with the Microsoft Kinect program being the most prominent.

Therefore, the present study aims to analyze the impacts of a specific home-based exercise program implemented in the maintenance stage of CR over a six-month period, on functional muscle strength of the lower limbs, physical activity, and exercise tolerance in individuals with CAD. This study compared the effects of a virtual reality format (*Kinect*), a conventional format (booklet), and a control group (CG) (conventional care).

Methodology

This study is part of a global project conducted by the authors. The methods are similar to the study by Vieira et al.,[9,10] later complemented by Vieira et al.,[11] and are properly referenced throughout this study.

Study design

This was a three-arm randomized clinical trial, with parallel groups, conducted during a 23-month period. This study was approved by the Research Ethics Committee of the *Centro Hospitalar do Porto, Departamento de Ensino, Formação e Investigação* (REF NO. 212/12 — 165-DEFI/157-CES) and of the *Escola Superior de Saúde, Instituto Politécnico do Porto* (1489/2012). All procedures were conducted according to the Declaration of Helsinki and the study was registered at *ClinicalTrials.gov* (NCT02753829).

Sample

According to Vieira et al.,[9,10] the sample was obtained from the *Centro Hospitalar do Porto*, and the target population consisted of individuals who had recently concluded the CR training stage at the CR and Prevention Unit. At the end of the training stage, the investigator in charge invited the individuals to participate in the study. According to Vieira et al.[10] enrollment of participants was carried out by the investigator in charge, with the support of a member of the CR and Prevention Unit, following the inclusion and exclusion criteria.[9-11]

Inclusion criteria:

- Both sexes, aged 40-75 years;
- Completed the CR training stage at the CR and Prevention Unit;
- Presence of stable CAD, without unstable angina or complex ventricular arrhythmia,[12-15] with or without percutaneous coronary intervention and with a final diagnosis of acute myocardial infarction or stable chest angina;
- Access to a computer, *Microsoft Windows* 7 or better.

Exclusion criteria

- Heart surgery;
- Stress test not finished due to extreme fatigue;
- Pregnant or willing to become pregnant;
- Presence of high CVD risk,[12,14,15] according to Pescatello et al.;[16]
- *Pacemaker*, presence of severe neurological, musculoskeletal or pulmonary disease and uncompensated metabolic disorders; reported dementia,[14-16] cardiomyopathies, and history of cardiorespiratory arrest not associated with acute myocardial infarction or cardiac procedures;
- Significant and uncompensated visual or hearing disabilities;[14]
- Being illiterate or having no knowledge of the Portuguese language;
- Attending or willing to attend a gym or a regular exercise program.

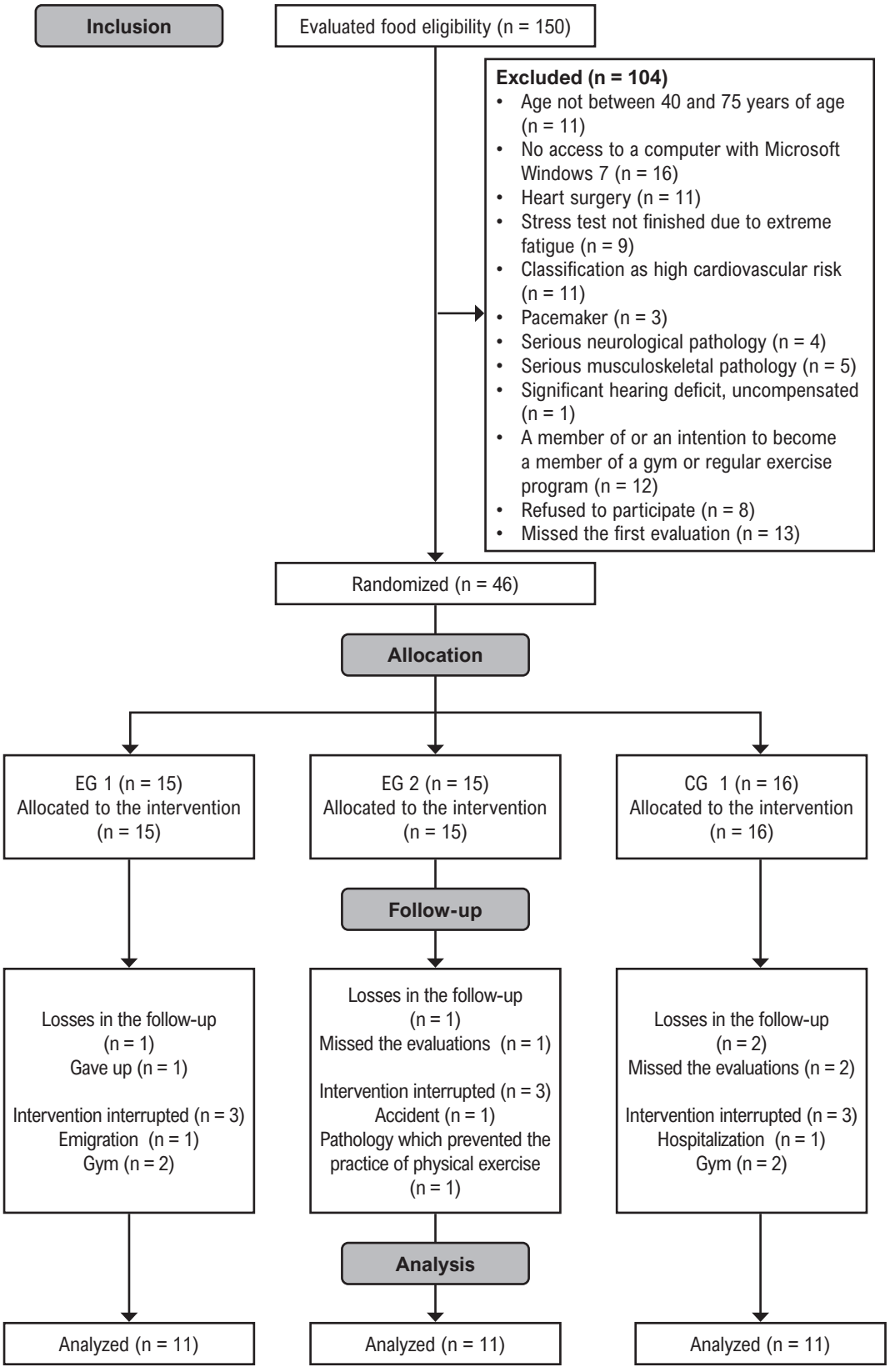

Figure 1 – Flowchart of the patients evaluated for eligibility (n = 150), according to Vieira et al.[11] and Vieira et al.[10]
CG: control group; EG1: experimental group 1; EG2: experimental group 2

According to Vieira et al.,[10,11] the flowchart of patient allocation is shown in Figure 1.[10,11] The participants were randomly assigned into three groups: Experimental Group 1 (EG1), participating in a home-based CR program, using a computer and the *Kinect* program (virtual reality format) (n = 15); Experimental Group 2 (EG2), participating in a home-based CR program, using a booklet (conventional format) (n = 15); and a CG which received conventional care only (n = 16). Block randomization was used and an allocation sequence based on a block size three was generated in a random number generator computer by an investigator who was not involved in the study.

According to Vieira et al.,[9,10] during the follow-up, four individuals were excluded from EG1 and EG2; and five were excluded from the CG. The final sample included 33 individuals: EG1, n = 11; EG2, n = 11; and CG, n = 11.

Data collection

According to Vieira et al.,[10] a pilot study was conducted with 10 individuals with characteristics similar to the target group to evaluate the feasibility of the exercises and the reliability of the instruments, as well as to improve the temporal organization of the data collection, the three groups were assessed at four time points. Figures 2 illustrates these time points and the tests administered at each of them. Data collection took place at the CR and Prevention Unit and at *Escola Superior de Saúde do Porto*.

At the inicial moment (M0), the participants filled out a questionnaire for selection and characterization of the sample, containing questions on patient's personal and demographic data, patient's medical history, and questions related to CR.[10] Medical history and data of each individual were collected and/or verified from the medical records.[11]

At M0, height was measured three times and average was taken.[10] The measurements were taken at the end of tidal breathing, in apnea, with participants standing barefoot, and with their heels, buttocks, and back of the head touching the wall.[17] Measures were taken using a two-meter non-elastic measuring tape, to the nearest 0.1 cm.[18] Also at M0, the body mass was evaluated with

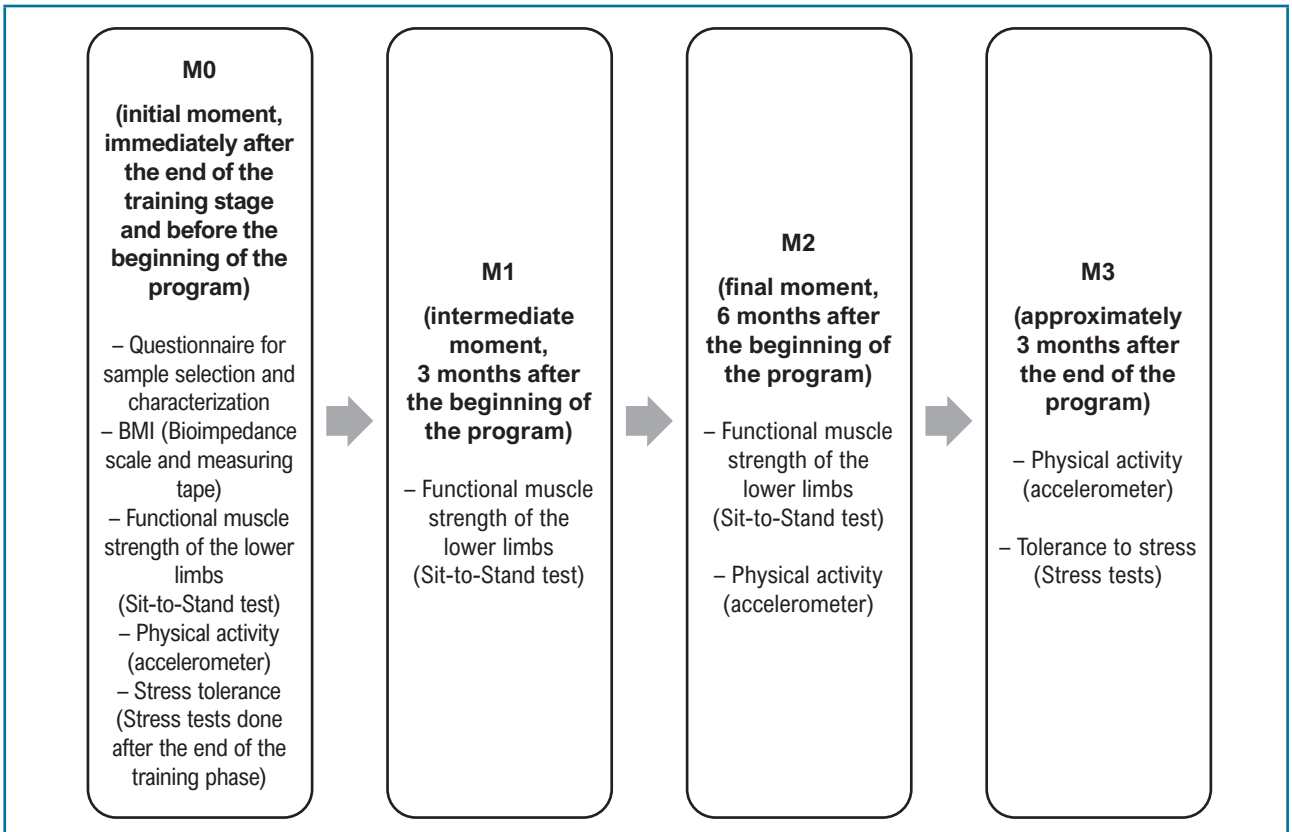

Figure 2 – Times of data collection and the instruments used.
BMI: body mass index

the use of a bioimpedance scale, Tanita InnerScan model BC-545 TM (USA), with a 150 Kg capacity and 0.1Kg precision, with the participants without clothes, barefoot, and with their heels aligned with the electrodes on the platform, without any metal objects close to them.[19] The participants were asked to refrain from alcohol, caffeine, and heavy meals in the 24 hours prior to the test; to urinate half an hour before being weighed; and to avoid intense physical activity for four hours before the test.[17,19] With body mass and height, the body mass index (BMI) was calculated:

$$(\text{BMI}) = \frac{\text{Body Mass (kg)}}{\text{Height}^2\ \text{(meter)}}$$

Each participant was classified as: normal weight, 18.5-24.9 Kg/m^2; overweight, 25-29.9 Kg/m^2; or Obese, ≥30 kg/m^2.[16]

To assess the study variables at M0, M,1 and M2, the sit-to-stand test was used (30 seconds). This test is useful to evaluate the functional muscle strength of the lower limbs[20] with a high validity when compared to the maximum weight lifted in the leg press exercise (r = 0.78, for men).[21] The intra-observer reliability in the present pilot study was excellent, Intraclass correlation index (ICC) = 0.99.[22]

The participants were asked to sit on an adjustable bench, leaning against the wall, positioned at a 43.2 cm in height, cross their arms, holding the opposite shoulder, with their feet positioned at the same width of the pelvis, and facing forward. First, each participant was asked to stand up and sit back three times to get used to the movement. Then, three test sessions of 30 seconds were performed, with a two-minute rest interval between them. Each participant was asked to sit with the back touching the back of the chair and, on the word "go", to stand up and sit back as quickly as possible. The number of correct repetitions over the three sessions was recorded.[20] A stopwatch (Samsung) was used to measure the time. At M0, M2, and M3, physical activity was measured with an ActiGraph accelerometer, model GT3X (ActiGraph, Pensacola, Florida, USA), and a recording sheet.[10]

The criterion validity was assessed by a direct comparison with the 6-minute walking test, as proposed by Thiese et al.[23] The accelerometer-derived count cutoffs proposed by Troiano et al.[25] were used for classification of physical activity level as sedentary (99 counts/minute (sedentary), mild (≥100 and ≤2019 counts/minute), and moderate to vigorous (≥ 2020 counts/minute).[25] The participants were instructed to wear the monitor for seven consecutive days, including at least four valid days (minimum of 600 minutes of data collection), and one weekend day.[25,26] The *ActiLife* software was used to program the recording of data every five seconds (*epoch*). The test was performed at the *Centro Hospitalar do Porto*, following the Bruce protocol.

To estimate and measure exercise tolerance, the following stress test parameters were collected at M0 and M3: metabolic equivalents (MET), test time, and the double product of two values — maximum heart rate (HR) x maximum systolic blood pressure. The tests were performed at Centro Hospitalar do Porto, following the Bruce protocol. According to Greenland et al.,27 this test has a sensitivity between 50% and 70%, and a specificity of 80%.

Intervention

As described by Vieira et al.,[11] participants from the three groups received education concerning CVD risk factors. Those from the exercise groups also had access to a specific exercise program: EG1, to a virtual reality program (*Kinect*); and EG2, to a booklet. The teaching process and the individual follow-up took place at the CR and Prevention Unit, at *Escola Superior de Saúde* in Porto, and/or at the participant's home.

All participants received a leaflet with information about CVD risk factors, nutritional habits, smoking, and physical activity. The leaflets were distributed to the participants, and their doubts were clarified. They also received a booklet with information about the study.[10] Before proceeding to specific exercise protocols, the subjects of the intervention groups attended three demonstrative classes, during which they received instructions on the home-based exercise protocol and preparation of the setting at home, with an interval of at least one day.[14,15] For EG1, the use of the *Kinect* was taught. The HR of participants were determined using the *Karvonen* formula; the reserve HR was based on the maximum HR in the stress test, and the baseline HR determined with the patient seated and relaxed. As in Vieira et al.,[10] the high-precision (±1% error or ±1 heartbeat per minute) Polar WearLink Coded transmitter (Polar watch F17) was used to measure exercise HR and the number of repetitions.

The exercise protocols performed by the EGs were adapted to participants' home environment, in a self-monitoring system format, and with two progressive levels covering the principles of overload, specificity and reversibility.[9,10]

The intensity and the number of repetitions were also monitored using the Borg scale (6-20) for perceived exertion,[9,10] with a target rating of 12 – 13 points(6-20).[15,16,29] According to Vieira et al.,[10] this would represent a validity of r = 0.62 as compared to the HR, and of r = 0.64, as compared to the maximum VO^2.[30] The exercise protocol was conducted over a six-month period,[14,15] three times a week,[31] at the most convenient time for each participant.[9,10] On the remaining days, a 30-minute daily walk was also recommended.[10,31]

The exercise protocol (Table 1) was designed by an expert with physical therapy certification and five-year experience in the field, and adapted from Noites et al.[32] The exercise protocol was composed of 10 exercises: one warm-up exercise, seven conditioning exercises (designed to improve cardiorespiratory and muscle endurance and/or strength), and two exercises to increase lower limb flexibility. Exercises 1, 4, 6, and 7 also aimed to improve flexibility of the thoracic curve, and exercises 5 and 3 aimed at increasing thoracic movement.

Conventional format

The EG2 followed the home-based exercise program, with possibility of consultation to a booklet with images and texts.[10]

Virtual reality format

The EG1 followed a virtual reality exercise protocol, with the use of *Kinect* (*Microsoft)* and a computer, installed in each participant's house.[9-11] As reported by Vieira et al.,[9,10] the *Kinect-RehabPlay* project, developed in the Engineering School of the University of Porto,[33] requires a software to monitor and evaluate the rehabilitation exercises performed by the participants and captured by the Kinect sensor, providing user with a real time feedback for the task.[33] This system provides a virtual physical therapist that helps with the exercise and provides feedback regarding participant's performance in the test. The participant is represented as a second avatar, who interacts with the physical therapist during the test.[33] The software uses the Microsoft Kinect to monitor individual movements and to make a correspondence with a predefined standard. This resource monitored the number of repetitions for each exercise, according to the pre-calculated value, which was defined in the individual's "exercise profile" and referred to in the program together with the respective exercise.

The virtual reality format therefore has key advantages, such as the visual feedback in real time to each exercise, as well as the indication, in real time, of the number of repetitions for each exercise. The participant only had to follow the program's instructions (visual and auditory).

Over the study period, individuals of the EG1 and EG2 groups registered the values of HR, Borg scale, and possible comments in an "Exercise Diary". This diary was used to check adherence to the exercises and, hence, compliance to the program.[9,10] The percentage of compliance was defined by the number of sessions completed, registered in the Exercise Diary, divided by the number of sessions prescribed (three sessions per week, for six months).

Recordings of training HR and Borg scale ratings at home were used for participant monitoring. Measurements of HR were performed either using a monitor, voluntarily acquired by the participant, or manually, as previously instructed.[11]

CG

The CG received conventional care routinely provided in the CR Prevention Unit.[11] Similarly to the EGs, the CG also received information about CVD risk factors and were encouraged to walk daily.[11]

For the three groups, telephone calls were scheduled at weeks 4, 10, and 22,[9,10] and for the EGs, home visits or face-to-face meetings (for re-evaluation and/or adjustment of the exercises) were also scheduled at weeks 6 and 18.[14,15] E-mails (or telephone messages) were sent weekly to the participants of the EGs, emphasizing the importance of their participation in the program.

Statistical analysis

For sedentary physical activity (assuming an 80% power and a 5% significance level), the power calculation revealed a training effect of 0.60, indicating the need for 30 participants in order to ensure statistical power to detect differences between the three groups at M3 (the assumed standard deviation was 69.9).

The statistical analysis was conducted with the IBM Statistical Package for the Social Sciences (SPSS) 22 software for Windows, with a 5% significance level and 95% confidence interval (CI). The Shapiro-Wilk test was also applied to verify the normality of the data. The variables were presented as "n" (%), and the continuous nominal variables, as their distribution complied with

Table 1 – Description of the exercise protocol, according to Vieira et al.[9,10]

Stages		Exercise	Description
Warm-up – 10 minutes		1. March "in place"	Flexion of the hips, bringing the right elbow forward at the same time that the left knee is up; repeat on the opposite side and keep alternating sides without moving forward. After 3 months, lift the knees up to the chest, at the waist level.
Conditioning	Strength 20–25 minutes (calculate the individual number of repetitions according to 65-70% of reserve HR)	2. Squatting	With feet hip-width, sitting into a squat position, keeping heels and toes on the ground; knees are bent to a 90-degree angle. After three months, perform two sets with a 1-minute break in between.
		3. "Crossing"	Keeping the "march in place" perform the first diagonal pattern (flexion, adduction, and external rotation movements of the shoulder) of the proprioceptive neuromuscular facilitation technique. After 3 months, perform two sets, with a 1-minute break in between of the second diagonal pattern (flexion, abduction, and external rotation movements of the shoulder).
		4. Ankle movement	Plantar dorsiflexion/flexion of the ankles, standing up. After 3 months, perform three sets with 1-minute break in between.
		5. Backwards movement of the arms	Keeping the "march in place", perform extension, abduction and external rotation of the glenohumeral joint at maximum amplitude. At the end of the movement, do 10 brief insistences. After three months, perform two sets with a 1-minute break in between.
		6. Sitting and standing	Sit on a chair with the upper limbs crossed over the chest. Sit in a controlled manner; after three months, lower the height of the chair.
	Endurance 35–45 minutes (calculate the individual number of repetitions according to 65-70% of reserve HR)	7. Stepping forward, sideways and backwards	Perform the semi-step forward and backward with bilateral flexion of the upper limbs, and lateral semi-step with abduction and external rotation of the upper limbs. After three months, perform two sets with a 1-minute break in between.
		8. Walking – 30 minutes	After three months, if possible, increase to 60 minutes.
Stretching – 6 minutes		9. Calf muscle stretching	Stretch the triceps surae 4 repetitions/maintain 15 s
		10. Anterior forearm muscle stretching	Stretch the wrist flexors 4 repetitions/maintain 15 s

HR: Heart Rate.

normality, were presented with the average and standard deviation.

In the characterization of the sample for the analysis of the groups at M0, when distribution complied with normality, the one-way ANOVA test and the Tukey post-hoc test were used for the continuous and nominal variables. In the case of nominal variables when there is no normality, the Fisher's exact test was used for independent samples.

For the remaining variables, since all were normally distributed, differences between the groups at the various moments (M0, M1, M2, and M3) and differences between the time points (M0-M1, M1-M2, M0-M2, M2-M3, and M0-M3) were evaluated by the one-way ANOVA test and the Tukey post-hoc test. Regarding adherence, the Student's t- test was used for independent samples to compare the two EGs.[34]

For within-group analysis, comparisons between M0, M1, M2, and M3 were made by the *ANOVA* test for repeated measurements and the *Bonferroni post-hoc* test. For the stress tests, comparisons between M0 and M3 were made by the paired samples *t*-test.[34]

Results

The final sample consisted of 33 male individuals. At M0, no significant difference was identified between the three groups ($p > 0.05$) in demographic, clinical data, or medications (Table 2). At M0, 63.6% of individuals in the EG1; 45.4% in EG2; and 36.4% in CG were classified as overweight according to BMI values, and in the three groups, physical exercise level was mild.

Concerning the percentage of adherence of the individuals to the program, for the three weekly sessions, the EG1 group showed an average of 82% in the first three months and 70% in the last three months, with an average of 77% over the six-month period. The EG2 group showed an average of 90% in the first three months and 75% in the last three months, with an average of 83% over the six-month period. No statistically significant differences were found between the two groups.

At M0, the three study variables were comparable, with no significant differences between the groups.

In the sit-to-stand test, concerning the functional muscle strength of the lower limbs, between-group analysis revealed significant at M1, with a significant increase in EG1 and CG when compared with EG2, as well as at M2, with a significant increase in EG1 and CG when compared with EG2 (Table 3). In the analysis of the difference variable (M0-M1, M1-M2, and M0-M2), no significant differences were found between the groups. In the within-group analysis, significant differences were identified, with a signficant increase in the number of stand-ups in EG1 ($F = 14,569$, $p = 0.001$) between M0 and M2 ($p = 0.003$) and between M1 and M2 ($p = 0.003$); in EG2 ($F = 4,124$, $p = 0.032$) between M1 and M2 ($p = 0.040$); and in CG ($F = 13,398$, $p = 0.001$) between M0 and M1 ($p = 0.007$) and between M0 and M2 ($p = 0.004$).

Analysis of the accelerometer data revealed significant differences in the lack of physical exercise (sedentary lifestyle) at M3, with a significant increase in EG1 when compared with CG (Table 4). In the analysis of the difference variable (M0-M2, M2-M3, and M0-M3), no signficant differences were found between the groups. Regarding the intra-group analysis, in EG1, significant differences were found in moderate to vigorous physical activity ($F = 6,787$, $p = 0.009$) and counts ($F = 4,556$, $p = 0.030$), with a significant reduction from M0 to M2, $p = 0.033$ and $p = 0.030$, respectively.

No differences were found in parameters of stress test or exercise tolerance between the three groups at the different time points (Table 5) or in the difference variable (M0-M3), as well as in the within-goup analysis.

Discussion

Analyzing the results of this study, it is important to emphasize the fact that these participants had already passed through the training stage, which promoted an improvement of functional skills and muscle strength, and encouraged the practice of exercise.[1] Thus, at the end of the training stage, several outcomes were already within the recommended levels, which may have limited their improvement in the maintenance stage. It is important to remember that the maintenance stage primarily intends to preserve the skills developed over the long term.[2] However, the evaluation of the functional muscle strength of the lower limbs, using the sit-to-stand test, showed a significant improvement in the group that underwent the virtual reality format, but only in comparison with those submitted to the conventional format (booklet) at three and six months. It was interesting note that there was an improvement in the CG compared to the conventional one, at three and six months. Although there were no significant differences between the groups at baseline, the CG showed a tendency for a better performance in the sit-to-

Table 2 – Characterization of the sample at M0 accroding to Vieira et al.[10] and Vieira et al.[9]

Variable		EG1 (n = 11)	EG2 (n = 11)	CG (n = 11)
Age (years)		55 ± 9.0	59 ± 11.3	59 ± 5.8
BMI (kilogram/meter^2)		27.4 ± 3.0	26.9 ± 4.7	28.0 ± 3.6
Counts (*counts*/minute)		355.4 ± 144.6	365.1 ± 138.5	424.9 ± 82.6
Professional status	Active	7 (64%)	2 (18%)	5 (45%)
	Not active	4 (36%)	9 (82%)	6 (55%)
Reason for hospitalization	ACS with no elevation of the ST segment	6 (55%)	6 (55%)	5 (45%)
	ACS with elevation of the ST segment	5 (45%)	3 (27%)	6 (55%)
	Stable chest angina and post-angioplasty	0	2 (18%)	0
Cardiovascular risk factors	Dislipidemia	10 (91%)	9 (82%)	8 (73%)
	Obesity	2 (18%)	2 (18%)	4 (36%)
	Diabetes *Mellitus*	2 (18%)	3 (27%)	1 (9%)
	Hypertension	5 (45%)	6 (55%)	8 (73%)
	Smoking	5 (45%)	5 (45%)	4 (36%)
	Family background	1 (9%)	1 (9%)	2 (18%)
Medications	Platelet Antiaggregants	9 (82%)	11 (100%)	10 (91%)
	Beta Blockers	8 (73%)	9 (82%)	8 (73%)
	Statins	9 (82%)	11 (100%)	11 (100%)
	Anti-hypertensives	4 (36%)	4 (36%)	6 (55%)
	Vasodilators	1 (9%)	3 (27%)	5 (45%)
	Calcium channel blockers	0	1 (9%)	1 (9%)
Cardiovascular risk	Low	7 (64%)	7 (64%)	8 (73%)
	Moderate	4 (36%)	4 (36%)	3 (27%)

Data are presented as mean and standard deviation or n(%). Cardiovascular risk was classified according to Pescatello et al.[16] CG: control group; EG1: experimental group 1; EG2: experimental group 2; BMI: body mass index; ACS: Acute Coronary Syndrome; M0: initial moment.

stand test, which agrees with the results obtained with the accelerometer. It is important to highlight that the virtual reality group showed improvements from the initial and the final stages, and like the conventional format group, from the intermediate to the final stage of the study. In contrast, the CG showed improvements from the initial to the intermediate stage, and from the initial to the final moment of the study.

In a study conducted by Mandic et al.,[35] older adults with CAD who participated in the maintenance stage of the CR program, had improved lower limb muscle strength, illustrating the important role of these programs in the long-term maintenance and/or delay of decline in muscle strength of the lower limbs, which is important in maintaining one's independence. These aspects demonstrate both the potential and the importance of the maintenance stage, even if in the present study no positive differences were found in comparison with the CG.

Three months after the end of the program, the virtual reality format group showed a significant decrease in physical activity level when compared to the CG. There was a significant decrease in the moderate to vigorous physical exercise level and in the counts at the end of the program in the virtual reality group, despite an increase (but not significant) in the subsequent three months. It is worth

Table 3 – Between-group analysis at different time points of the sit-to-stand test

Variable	Group	M0 X ± SD	M1 X ± SD	M2 X ± SD
Sit-to-stand test **(number of stand- ups)**	EG1	14.3 ± 2.8 (n = 11)	19.5 ± 7.7 (n = 11)	23.0 ± 7.7 (n = 11)
	EG2	10.8 ± 4.6 (n = 11)	11.9 ± 4.7 (n = 11)	14.6 ± 4.6 (n = 11)
	CG	16.0 ± 6.8 (n = 11)	19.6 ± 8.2 (n = 10)	22.3 ± 8.8 (n = 11)
	p	0.062[a]	**0.023**[a]	**0.018**[a]
	Post-hoc	–	EG1 > EG2 p = **0.042**[b] EG2 < CG p = **0.046**[b]	EG1 > EG2 p = **0.027**[b] EG2 < CG p = **0.046**[b]

Data presented as mean (X) and standard deviation (SD). CG: control group; EG1: experimental group 1; EG2: experimental group 2; M0: initial moment; M1: intermediate moment (3 months); M2: final moment (6 months); SD: standard deviation.
[a] p-values with the ANOVA *test. [b] p-values for the* Tukey post-hoc *test.*

mentioning that the cut-off points adopted in the present study were the highest described in the literature, and thus stricter.[23] These results can still be justified by the fact that the participants, at the beginning of the study, came from the training stage and, for this reason, were quite disciplined, and such discipline decreased over the six-month period, primarily due to the psychological distancing from the cardiac event, even with the stimulation of the new, virtual reality. Nevertheless, regarding the moderate to vigorous physical exercise, as well as the counts, it seems that, after six months, the participants of the virtual reality group began to see the benefits of the new tool, which may be the underlying reason for the positive results in discipline and adaptation to exercise promoted by the virtual reality system over the six-month period.

Considering the results obtained, it would be important to obtain a daily record of physical activity from participants, even paper-based records, for a more detailed analysis.

All participants achieved the recommended level of physical activity of at least 150 minutes of moderate-intensity exercise per week.[36] Both in the beginning (which was expected, since participants had just completed the training stage) and at the end of the exercise program.

We can therefore affirm that the results of physical activity reflected in the maintenance of exercise tolerance, which was evaluated approximately three months after the end of the program due to hospital protocol. It would also be important to have exercise test data at the end of the program and compare them with those at three months thereafter. In the present study, nearly 75% of the individuals had a functional capacity equal to or greater than 10 METs before beginning the study program. Although this was expected, as participants came from the training stage, it made it difficult to detect the positive impact of the intervention.[37]

The METs have proven to be important to measure functional and prognostic capacity, be it in healthy individuals or in those with CVD, given that an increase of 1 MET corresponds to an increase of 12% in survival rates.[38] The time of stress is also an aspect to bear in mind, since it also reflects the capacity of tolerance to stress, considering that, for each increase of 1 minute in the duration of the stress test, a 7.9% decrease was found in mortality among men.[39] In future studies, it is important to evaluate how the double product at rest, following a six-month exercise program relates with the maximum double product, to indirectly verify how this group of exercises influences the myocardial capacity.[40]

In this sample, according to Vieira et al.,[10] there was a good average adherence to the exercise program (considering the three-weekly sessions) in the two groups,[32,41] greater than 65% in both virtual reality and conventional formats,[32] in the first and in the last three

Table 4 – Between-group analysis of accelerometer data at different time points

Variable		Group	M0 X ± SD	M2 X ± SD	M3 X ± SD
Accelerometer	Sedentary physical activity (minutes/day)	EG1	646.2 ± 66.3 (n = 11)	675.2 ± 54.5 (n = 9)	677.7 ± 30.6 (n = 9)
		EG2	592.6 ± 82.5 (n = 11)	601.4 ± 95.0 (n = 11)	601.2 ± 89.1 (n = 11)
		CG	607.2 ± 81.0 (n = 10)	591.7 ± 62.6 (n = 10)	576.0 ± 90.0 (n = 9)
		p	0.257[a]	0.043[a]	**0.023**[a]
		Post- hoc	-	NS	EG1 > CG p = **0.024**[b]
	Mild physical activity (minutes/day)	EG1	116.8 ± 31.5 (n = 11)	112.3 ± 16.8 (n = 9)	110.3 ± 22.8 (n = 9)
		EG2	143.9 ± 42.2 (n = 11)	128.3 ± 49.1 (n = 11)	121.0 ± 39.1 (n = 11)
		CG	153.4 ± 59.1 (n = 10)	152.2 ± 51.4 (n = 10)	175.1 ± 96.0 (n = 9)
		p	0.170[a]	0.145[a]	0.063[a]
	Moderate to vigorous physical activity (minutes/day)	EG1	59.4 ± 32.5 (n = 11)	40.9 ± 18.6 (n = 9)	58.4 ± 31.6 (n = 9)
		EG2	54.6 ± 22.3 (n = 11)	44.2 ± 16.4 (n = 11)	47.2 ± 14.5 (n = 11)
		CG	71.9 ± 17.5 (n = 10)	57.1 ± 16.4 (n = 10)	60.4 ± 10.9 (n = 9)
		p	0.286[a]	0.104[a]	0.308[a]
	Counts (*counts*/minute)	EG1	355.4 ± 144.6 (n = 11)	279.9 ± 117.4 (n = 9)	341.0 ± 146.9 (n = 9)
		EG2	365.1 ± 138.5 (n = 11)	301.2 ± 113.8 (n = 11)	317.2 ± 71.3 (n = 11)
		CG	424.9 ± 82.6 (n = 11)	371.3 ± 81.7 (n = 10)	407.8 ± 99.5 (n = 9)
		p	0.411[a]	0.154[a]	0.182[a]

Data presented as mean (X) and standard deviation (SD). CG: control group; EG1: experimental group 1; EG2: experimental group 2; M0: initial moment; M2: final moment (6 months); M3: 3 months after the end of the program.
[a] p-values with the ANOVA *test. [b] p-values for the* Tukey post-hoc *test.*

months, with no significant difference between the groups. Nonetheless, it is important to consider that the virtual reality format group had a higher number of physically active individuals, which may have influenced the adherence to the exercise program. The decline in adherence over time may indicate either that the participants have difficulty to maintain the physical exercise habits, or that the protocol, as well as the changes implemented at three months, are insufficient motivators at long-term.

The truth is that, according to García-Bravo et al.,[42] virtual reality technology and videogames can increase the motivation and adherence to CR programs. According to Bond et al.,[43] although the efficiency of the exercise games has not been cleared yet, virtual reality technology and exercise games have quickly become

Table 5 – Between-group analysis of the accelerometer data at different time points

Variable		Group	M0 X ± DP	M3 X ± DP
Stress test	MET	EG1	11.9 ± 1.6 (n = 10)	11.9 ± 1.3 (n = 10)
		EG2	10.8 ± 1.9 (n = 11)	10.7 ± 1.9 (n = 10)
		CG	11.2 ± 2.6 (n = 11)	11.1 ± 2.7 (n = 9)
		p	0.497[a]	0.395[a]
	Test time (seconds)	EG1	690.5 ± 120.9 (n = 10)	693.90 ± 98.4 (n = 10)
		EG2	612.0 ± 148.1 (n = 11)	600.7 ± 145.9 (n = 10)
		CG	639.6 ± 191.0 (n = 11)	631.7 ± 193.9 (n = 9)
		p	0.520[a]	0.379[a]
	Maximum double product	EG1	23032.0 ± 3536.2 (n = 10)	24646.7 ± 2946.2 (n = 9)
		EG2	22853.2 ± 4198.7 (n = 11)	23629.5 ± 5024.6 (n = 10)
		CG	20840.0 ± 4223.7 (n = 11)	24119.4 ± 5673.9 (n = 9)
		p	0.383[a]	0.896[a]

Data presented as mean (X) and standard deviation (SD). CG: control group; EG1: experimental group 1; EG2: experimental group 2; M0: initial moment; M3: three months after the end othe program; MET: metabolic equivalents
[a] *p-values with the* ANOVA *test.*

adequate alternatives, equivalent to traditional exercise programs. According to Thomas et al.,[44] in a statement from the American Association of Cardiovascular and Pulmonary Rehabilitation, the American Heart Association, and the American College of Cardiology, home-based CR is an alternative in selected patients who are clinically stable and at low to moderate risk, who would not be eligible to participate in the CR. New technologies, especially the virtual reality, due to their great potential, may well be the path to follow and to invest in, overcoming many of the limitations associated with CR programs; however, further study is required.

As limitations of this study, it is important to highlight the difficulty in objectively monitoring adherence, the small number of participants, which hinder any extrapolation of these results to the general population and. Further studies are needed to test this intervention in a larger sample of individuals of both sexes and stratified by age, BMI, and physical activity, as well as in the CR training stage, to determine the most accurate way to monitor adherence to the exercise program and behavioral.

Conclusions

In the present sample, the home-based virtual reality training performed in the CR maintenance stage over a six-month period, did not show significantly better results concerning physical capacity or exercise tolerance compared with the CG. As regards the functional muscle strength of the lower limbs, the

group submitted to the virtual reality exercise program showed significantly higher values, but only when compared to the group submitted to the exercise program in conventional format. The virtual reality exercise program is a promising alternative in CR, and further studies with larger samples and the CR maintenance stage are needed.

Author contributions

Conception and design of the research: Vieira A, Melo C, Noites A, Machado J, Mendes J; acquisition of data: Vieira A, Machado J; analysis and interpretation of the data and critical revision of the manuscript for intellectual content: Vieira A, Melo C, Noites A; statistical analysis and writing of the manuscript: Vieira A.

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No potential conflict of interest relevant to this article was reported.

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Ethics Approval and Consent to Participate

This study was approved by the Ethics Committee of the Centro Hospitalar do Porto, Departamento de Ensino, Formação e Investigação and Escola Superior de Saúde, Instituto Politécnico do Porto under the protocol numbers 212/12 - 165-DEFI/157-CES and 1489/2012. All the procedures in this study were in accordance with the 1975 Helsinki Declaration, updated in 2013. Informed consent was obtained from all participants included in the study.

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