Rev Bras Cir Cardiovasc 2013;28(2):281-9

The use of the virtual reality as intervention tool in the postoperative of cardiac surgery

O uso da realidade virtual como ferramenta complementar no pós-operatório de cirurgia cardíaca

Lucas de Assis Pereira Cacau[2], Géssica Uruga Oliveira[1], Luana Godinho Maynard[1], Amaro Afrânio de Araújo Filho[1], Walderi Monteiro da Silva Junior[2], Manoel Luiz Cerqueria Neto[2], Angelo Roberto Antoniolli[1], Valter J. Santana-Filho[2]

DOI: 10.5935/1678-9741.20130039

RBCCV 44205-1468

Abstract

Introduction: **Cardiac surgery has been the intervention of choice in many cases of cardiovascular diseases. Susceptibility to postoperative complications, cardiac rehabilitation is indicated. Therapeutic resources, such as virtual reality has been helping the rehabilitational process. The aim of the study was to evaluate the use of virtual reality in the functional rehabilitation of patients in the postoperative period.**

Methods: **Patients were randomized into two groups, Virtual Reality (VRG, n = 30) and Control (CG, n = 30). The response to treatment was assessed through the functional independence measure (FIM), by the 6-minute walk test (6MWT) and the Nottingham Health Profile (NHP). Evaluations were performed preoperatively and postoperatively.**

Results: **On the first day after surgery, patients in both groups showed decreased functional performance. However, the VRG showed lower reduction (45.7±2.3) when compared to CG (35.06±2.09, *P*<0.05) in first postoperative day, and no significant difference in performance on discharge day (*P*>0.05). In evaluating the NHP field, we observed a significant decrease in pain score at third assessment (*P*<0.05). These patients also had a higher energy level in the first evaluation (*P*<0.05). There were no differences with statistical significance for emotional reactions, physical ability, and social interaction. The length of stay was significantly shorter in patients of VRG (9.4±0.5 days vs. 12.2 ± 0.9 days, *P*<0.05), which also had a higher 6MWD (319.9±19.3 meters vs. 263.5±15.4 meters, *P*<0.02).**

Conclusion: **Adjunctive treatment with virtual reality demonstrated benefits, with better functional performance in patients undergoing cardiac surgery.**

Descriptors: **Video games. Cardiac surgical procedures. Motivation. Physical therapy modalities.**

Veja reportagem sobre o tema desenvolvido neste artigo acessando o link: http://globotv.globo.com/tv-sergipe/se-tv-2a-edicao/v/games-sao-terapia-para-pacientes-cardiacos-em-aracaju/2194856/

1. Graduate Program in Health Science, Federal University of Sergipe, Aracaju, SE, Brazil.
2. Department of Physical Therapy, Federal University of Sergipe, Aracaju, SE, Brazil.

Correspondence address:
Lucas de Assis Pereira Cacau
Department of Physical Therapy, Federal University of Sergipe
Rua Cláudio Batista, s/n. – Santo Antonio – Aracaju, SE
Brazil – Zip code 49060-100
E-mail: lucas.cacau@yahoo.com.br

Article received on January 3rd, 2013
Article accepted on May 17th, 2013

Abbreviations, acronyms & simbols	
6MWT	Six minutes walk test
BP	Blood pressure
CG	Control group
CR	Cardiac rehabilitation
CVD	Cardiovascular diseases
FIM	Functional Independent Measure
HR	Heart rate
ICF	Informed consent form
ICU	Intensive care unit
MET	Metabolic equivalents of task
MV	Mechanical ventilation
NHP	Nottingham Health Profile
PO	Postoperative day
RR	Respiratory rate
SpO_2	Peripheral saturation of oxygen
SPSS	Statistical Package for the Social Sciences
VR	Virtual reality
VRG	Virtual reality group
WHO	World Health Organization

Resumo

Introdução: **A cirurgia cardíaca tem sido a intervenção de escolha em muitos casos de doenças cardiovasculares. Pela susceptibilidade a complicações pós-operatórias, a reabilitação cardíaca é indicada. Recursos terapêuticos, como a realidade virtual, tem favorecido o processo reabilitacional. O objetivo do estudo foi avaliar o uso da realidade virtual na reabilitação funcional de pacientes pós-cirurgia cardíaca.**

Métodos: **Os pacientes foram randomizados em dois grupos, Realidade Virtual (GRV, n=30) e Grupo Controle (GC, n=30). A resposta ao tratamento foi avaliada por meio do Questionário de Medida de Independência Funcional (MIF), Teste de caminhada de 6 minutos e do Perfil de Saúde de Nottingham (PSN). Os questionários foram aplicados no pré e pós-operatório.**

Resultados: **No primeiro dia de pós-operatório, os pacientes de ambos os grupos demonstraram diminuição do desempenho funcional. No entanto, essa perda foi menor no GRV (45,7±2,3) em relação ao GC (35,06±2,09, P<0,05), sem diferença significativa no momento da alta hospitalar (P>0,05). Na avaliação do PSN, foi observada menor intensidade da dor no terceiro momento de avaliação no GRV (P<0,05). Esses pacientes também apresentaram maior nível de energia na primeira avaliação (P<0,05). Não foram encontradas diferenças com significância estatística para reações emocionais, habilidade física e interação social. O tempo de internação foi significativamente menor nos pacientes do GRV (P<0,05), que também apresentaram maior distância percorrida no TC6 (319,9±19,3 metros vs. 263,5±15,4 metros, P<0,02).**

Conclusão: **O tratamento com a realidade virtual foi eficaz em proporcionar melhor desempenho funcional pós-operatório.**

Descritores: **Jogos de vídeo. Procedimentos cirúrgicos cardíacos. Motivação. Modalidades de fisioterapia.**

INTRODUCTION

Cardiovascular diseases (CVD) have had great impact on the world heath scenario [1]. In the USA, one in every three adults have one or more CVD and the total number of patients that have undergone cardiovascular surgeries have increased 33% in the last decade, which accounts for around $ 500 billion a year for CVD and $ 155 billion for hospitalization [2].

Approximately one million hospitalizations and around 30% of deaths in Brazil are due to CVD. It is also the number one cause of death among the elderly. Although clinical treatment have made the approach to individuals with cardiovascular diseases less invasive [3], the cardiac surgery is the intervention adopted in some cases of cardiovascular diseases and it aims at increasing patients' life expectancy and life quality [4]. In 2011, around 100 thousand cardiac surgeries were performed in Brazil in more than 170 centers around all the Brazilian states [5].

Patients that have undergone cardiac surgeries are likely to develop complications during and after the operations, such as pain, respiratory complications, functional loss, neurocognitive decline, depression and increased anxiety [6-9]. These complications are the main causes of morbidity and mortality after a cardiac surgery [10], contributing for the increase of length of hospital stay and its cost [11,12].

In the past few years, the development of a more accurate diagnosis and therapeutic methods has dramatically reduced mortality and negative outcomes of these diseases [13]. Nevertheless, the physiotherapeutic rehabilitation protocols have became necessary in the prevention of post-operatory complications [14].

The benefits of inserting a post-operated patient in a cardiac rehabilitation (CR) program are well established [14] and physiotherapy is highlighted as a fundamental tool in the period of post cardiac surgery, acting from the evaluation of mechanical ventilation (MV) weaning, in the prevention of pulmonary complications, to the caring of patients' functional capacity. However, the treatment faces some restrictions due to pain, fear, insecurity and post-operatory unwillingness [15].

Focusing on greater development in the rehabilitation processes, virtual reality (VR) has been described as an additional tool for the physiotherapeutic protocols [16,17] and for the auxiliary treatment of many diseases [18-20]. The insertion of VR as a support for the physiotherapeutic treatment brings several benefits, including less pain after painful procedures [21] and greater motivation during treatment [22].

VR may use advanced interface technologies where the user is not in front of a monitor, but immersed in a tridimensional world generated by the software [22]. In order to achieve its goals during treatment, this virtual environment works with specific functions wished to be recovered, mainly in attention, memory, physical strength and using challenging strategies [22].

The main reason for the use of treatment strategies with VR is based on the necessity of adding a motivation factor, which helps patients use movements expected by physiotherapeutic treatment. Thus, helping in the recuperation process [21,22].

METHODS

This is a controlled clinical trial, longitudinal, contemporary and quantitative study. The study protocol was approved by the Human Research Ethics Committees of the Federal University of Sergipe (CAAE number 0180.0.107.107-11) and was conducted at the Fundação de Beneficência Hospital Cirurgia, Aracaju, Sergipe, Brazil from August 2010 to June 2011.

The study included 102 individuals that have undergone elective cardiac surgery (coronary artery bypass grafting and / or valve replacement). In order to be included in the study the patient should agreed to participate in the research and signed the informed consent form (ICF). It was excluded patients with age over 75 years, patients hemodynamically instable, presence of arrhythmia or respiratory distress during the protocol; use of mechanical ventilation on the first postoperative day, patient dropouts removing the ICF, patients that present psychiatric disorders, muscular or neurological disease that would preclude protocol execution (Figure 1).

Consort

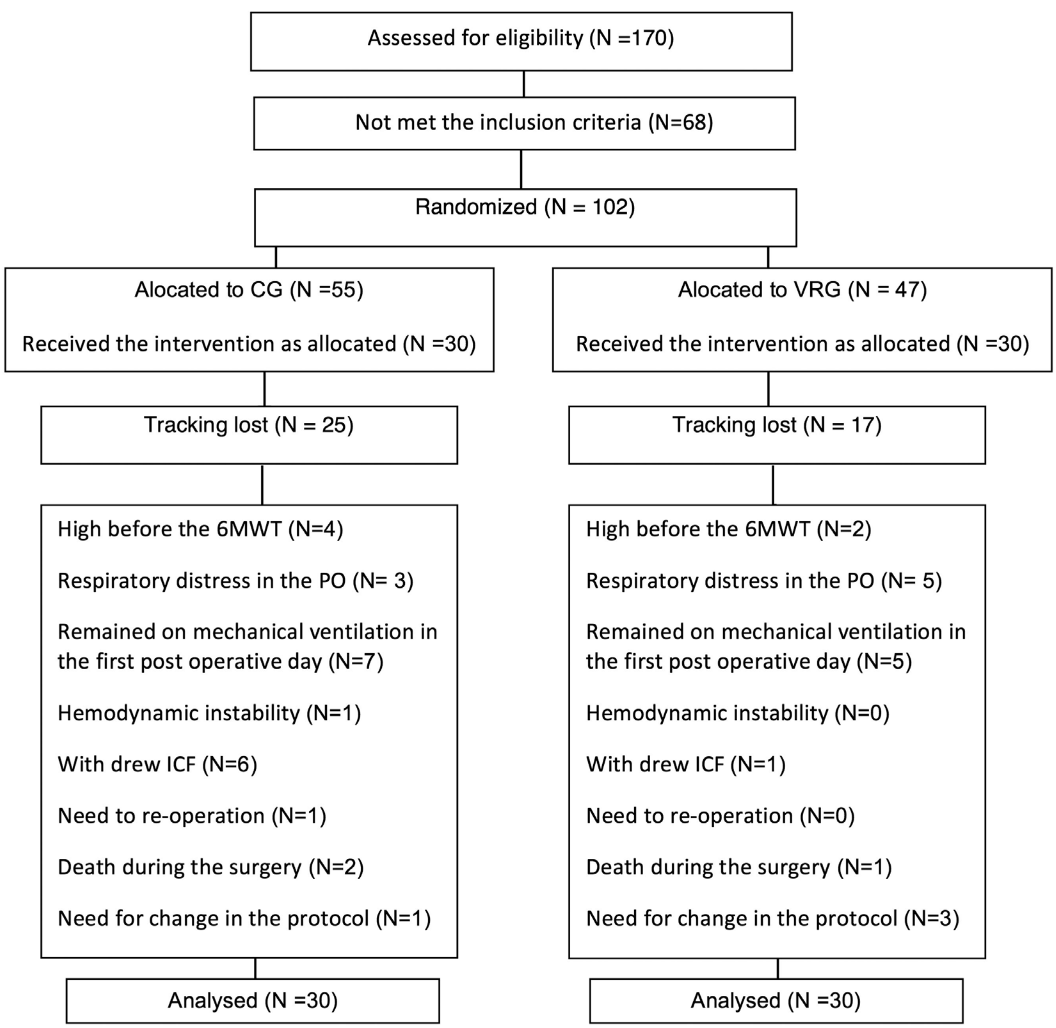

Fig. 1 – Diagram representing the flow of participants in each study phase

Functional performance was evaluated on admission and demographic characteristics (age and gender) and information about surgical procedure were also collected. After these initial evaluations patients were divided into two groups by using randomized sampling. Patients allocated in control group (CG), performed conventional physical therapy treatment twice a day (in the morning and afternoon). The treatment protocol included: breathing exercises, airway clearance techniques, metabolic exercise and motor exercise [20]. Patients allocated in virtual reality group (VRG) were treated twice a day (in the morning and afternoon), performing the same techniques than conventional treatment however the motor exercise was performed using virtual reality. The application of virtual reality and kinesiotherapy were performed in accordance with the phases of rehabilitation and energy expenditure (Metabolic Equivalent of Task MET) [21,22]. Through this method, the exercise is prescribed by determining the percentage of exercise capacity of the individual and by selecting the activities included in the series [23-26].

All patients had their functional performance reassessed on the first, third, postoperative day (PO) and at the discharge day. The Six minutes walk test (6MWT) was also performed on the day the patientes were discharged. The length of hospitalization was monitored in both groups.

Functional Performance Evaluation

The Functional Independence Measure (FIM) is an 18-item ordinal scale (range: 0 to 126) with seven levels per item (from complete independence to total assist) that includes assessment of disability in the areas of self-care, sphincter control, mobility, locomotion, communication, psychosocial adjustment, and cognitive function [27]. The physical FIM sub-score refers to the summed sub-scores for self-care, sphincter control, mobility, and locomotion items, whereas cognitive FIM sub-score includes the sub-scores for communication, psychosocial adjustment, and cognitive function. It is internationally accepted as a measure of functionality [28] and was already validated to be used in Brazil [29].

Health profile

Nottingham Health Profile (NHP) is a generic life quality evaluation instrument, originally developed to evaluate patients' quality of life with chronicle diseases [25].

It is a yes/no question survey made of 38 items based on the classification of incapacity described by the World Health Organization (WHO). The survey measures six dimensions of health including: physical mobility, pain, social isolation, emotional reactions, energy, and sleep. The evaluator quantifies each positive answer as score one (1), and each negative answer as zero (0), to a maximum of 38 points [26].

Using an easily comprehensible language, the NHP gives a simple measure of someone's physical, emotional and social health. The NHP is clinically valid for distinguishing patients with different levels of dysfunction and for detecting important alterations in the patient's health status.

An algorithm was used to quantify the values within its domains, which uses the American version for data interpretation.

As for the analysis, a delta difference was used between the pre-operatory and the 1st postoperative day (PO) (delta 1), between the pre and the 3rd PO (delta 2), and between the pre and the day of hospital discharge (delta 3).

Six-minute walk test (6MWT)

The 6MWT was used to determine the walking capacity by measuring the maximum distance that an individual is able to walk within six minutes [30]. Thus, the 6MWT was performed identically in both groups. A 30-m indoor course was delineated with cones, which were arranged in a straight line on level ground. While the patient remained seated, respiratory rate (RR), heart rate (HR), blood pressure (BP), peripheral oxygen saturation (SpO_2) and subjective sensation of dyspnea (modified Borg scale) were obtained [31].

Each participant was instructed to complete as many laps as possible in 6 min, walking briskly, but without running or jogging. At the end of every minute, the patient was informed of how many minutes remained and was given verbal encouragement in a neutral tone of voice ("You're doing well" and "Keep up the good work"). The investigator stood at one end of the walking course holding a stopwatch [31].

After 6 min, the patient was instructed to stop. The distance from the cone to the spot where the patient stopped was then measured. While the individual remained seated, HR, RR, SpO_2, and Borg scale scores [32] were again obtained, immediately after the test and after a 3-min rest period. Each test was administered to one individual at a time. It was explained to participants that, during the test, they could stop walking at any time if they experienced discomfort, but that test time would continue to be counted [32].

Statistical Analysis

The Statistical Package for the Social Sciences (SPSS), version 17.0 (SPSS Inc., Chicago, IL), was used for data analysis. Descriptive statistics (mean±SEM) were calculated for age and perfusion time in both groups. Frequency counts were calculated for gender and type of surgery. All variables were consistent with normal distribution (Shapiro Wilks), except perfusion time. Mann-Whitney (Test U) test was conducted to compare perfusion time between groups. FIM (physical, cognitive and total domain) scores were analyzed by two-way ANOVA. Bonferroni test was used for post hoc analyses. The Student t test was used to compare 6MWT, length of hospitalization and age. Chi-square (X^2) was used to compare type of surgery between the groups. The threshold of statistical significance was set at $P<0.05$.

RESULTS

In this study, no differences were observed between groups regarding to age, gender, surgical type and perfusion time (Table 1). When performing the analysis between the groups at the motor and total FIM score there were significant differences only on the 1st PO (Figure 2). The comparison between groups at the cognitive FIM score showed no significant difference (Figure 3).

NHP was applied and evaluated through its six domains and total score. No significant difference was observed in the total score between the CG and the VRG (*P*>0.05). However, this difference was significant in treatment time in both groups (*P*<0.05).

As for the pain domain, a positive reply was noticed in treatment time, reflecting lower score (*P*<0.05) among deltas 1, 2 and 3 as well as the type of treatment, with a significant statistical improvement in the VRG in delta 3 (*P*<0.05) (Figure 4). In delta 1 of the NHP energy level domain (Figure 5), there was significant improvement in the VRG, when compared to the CG (*P*<0.05). During treatment improvement remained significant as for treatment time (*P*<0.0001) in both groups, with no significant difference between them in the other deltas of the evaluation for this domain.

In the emotional reaction, sleep, physical abilities and social interaction domains, evaluated by NHP, both treatments proved effective in optimizing recovery (*P*<0.05), with no significant difference between the CG and VRG (*P*<0.05).

Moreover, VRG showed lower length of hospitalization (Figure 6) (CG 12.2 ± 0.9 days and VRG 9.46 ± 0.5 days, *P*<0.05) and higher walking capacity, evaluated by 6MWT (Figure 7) (CG 263.5 ± 15.4 meters and VRG 319.96 ± 19.3 meters, *P*<0.05).

Table 1. CG - Control Group, VRG - Virtual Reality Group. Data were analyzed using the X^2 test. *P*> 0.5 - no statistically significant.

	VRG (n=30)	CG (n=30)	*P* value
Age (years)	49.2±2.6	52±2.4	>0.05
Gender (male/female)	13/17	16/14	>0.05
Surgery			
Coronary artery bypass graft surgery	16	12	>0.05
Valve replacement surgery	14	18	>0.05
Perfusion time (minutes)	93.1±40	99.25±26	>0.05

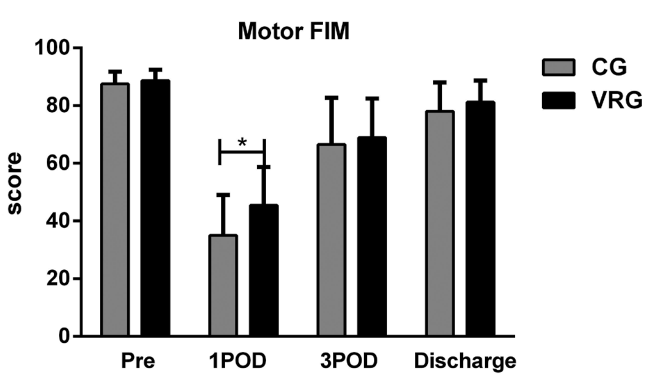

*Fig. 2 – Effects of treatment on the motor FIM score in patients undergoing cardiac surgery. CG = Control Group; VRG = Virtual Reality Group; FIM = Functional Independence Measure, Pre - Pre operative; 1POD = first postoperative day; 3POD = third postoperative day; Discharge = Discharge day. Data were analyzed using two-way ANOVA (*VRG x CG at 1st PO, P< 0.05)*

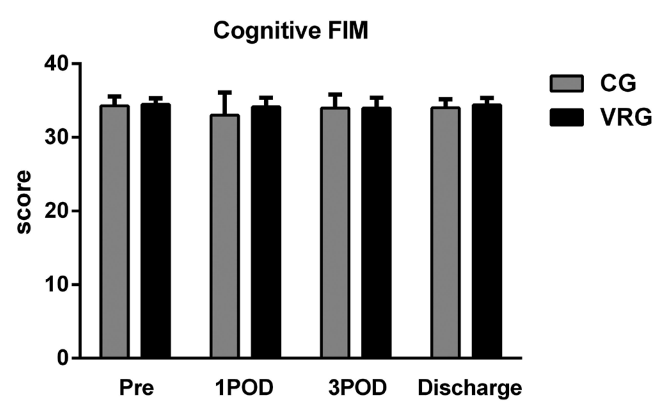

Fig. 3 – Effects of treatment on the cognitive FIM score in patients undergoing cardiac surgery. CG = Control Group; VRG = Virtual Reality Group; FIM = Functional Independence Measure, Pre = Pre operative; 1POD = first postoperative day; 3POD = third postoperative day; Discharge = Discharge day. Data were analyzed using two-way ANOVA. No differences were observed

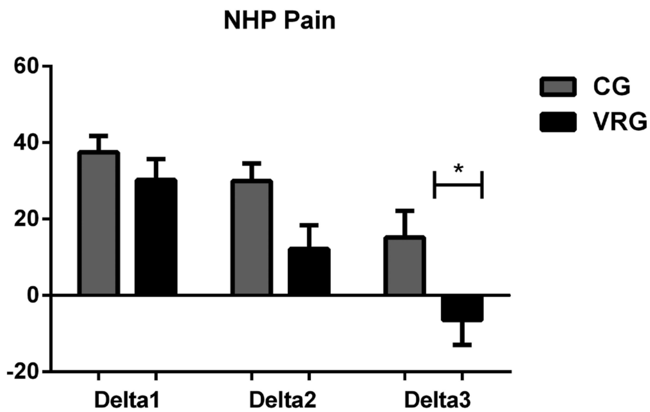

*Fig. 4 – Effect of cardiac rehabilitation versus time of post surgical pain in the field of NHP in CG and VRG. NHP = Nottingham Health Profile; CG = Control Group; VRG = Virtual Reality Group; Delta 1 (difference of pre-operative score for first postoperative day); Delta 2 (difference of pre-operative score for third postoperative day) and Delta 3 (difference of preoperative score for the discharge day). Data were analyzed using two-way ANOVA (Delta 3 *VRG x CG, P<0.05)*

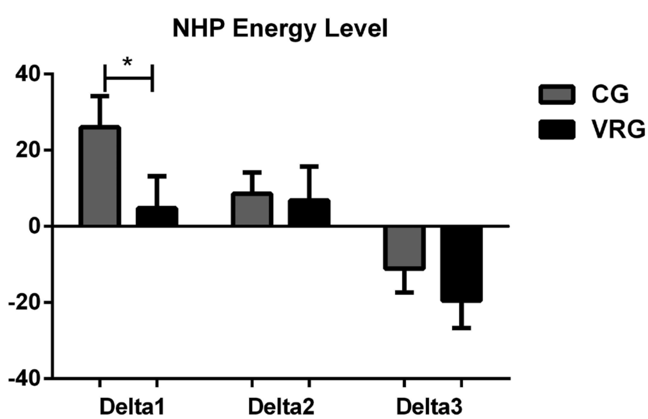

*Fig. 5 – Effect of cardiac rehabilitation versus time of post surgical energy level in the field of NHP in CG and VRG. NHP = Nottingham Health Profile; CG = Control Group; VRG = Virtual Reality Group; Delta 1 (difference of pre-operative score for first postoperative day); Delta 2 (difference of pre-operative score for third postoperative day) and Delta 3 (difference of preoperative score for the discharge day). Data were analyzed using two-way ANOVA (Delta 1 *VRG x CG, P<0.05)*

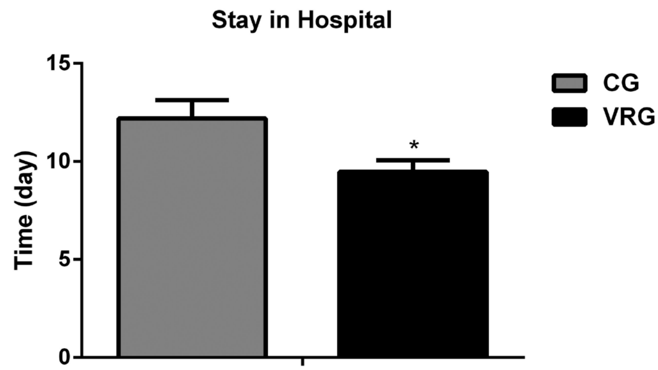

*Fig. 6 - Total length of stay between CG and VRG. CG - Control Group; VRG - Virtual Reality Group; Data were analyzed using Student t test (*VRG x CG, P<0.05)*

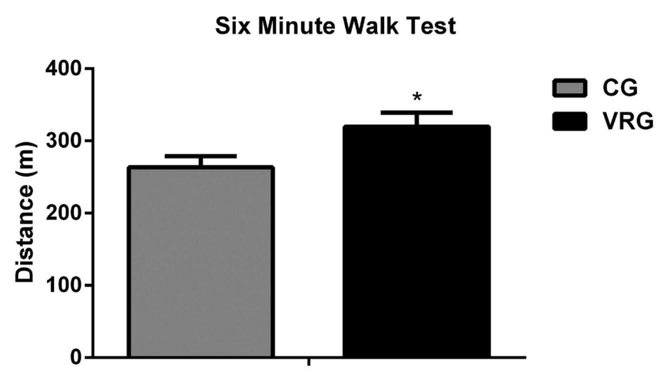

*Fig. 7 - Mean distance covered in the 6MWT between the groups. CG - Control Group; VRG - Virtual Reality Group; 6MWT – Six minute walk test. Data were analyzed using Student t test (*VRG x CG, P<0.05)*

DISCUSSION

In this study, VR, as an adjunct treatment to the rehabilitation protocols, has shown benefits in functional performance, higher energy levels, less pain and better walking capacity in patients submitted to cardiac surgery. Moreover, it provided faster recovery and early hospital discharge to operated patients.

Patients in the postoperative period of cardiac surgery are susceptible to developing operatory complications that contribute to functional loss [27-29]. There was a reduction in the postoperative functionality in patients of both studied groups evaluated with total FIM, with a gradual improvement in both groups until the hospital discharge day.

This functional loss has not suffered influence from these patients' cognitive function. Although commonly found, they were not noticed in the patients of this study [8].

The greatest loss was noticed on the 1st PO, because this is the postoperative critical moment. Besides the pain in the surgical region, the patient was still at the intensive care unit (ICU), requiring closer monitoring and consequently greater devices that contribute to bed mobility restriction, such as electrodes, accesses, as well as the use of tubes and drains, which besides promoting restriction, they also contribute to pain, fear, insecurity and increase of anxiety.

Despite the notorious functional loss in patients of both groups, patients in the VRG evolved with lower decrease in their functional performance when compared to patients in the

CG. Thus showing significant difference on the 1st POD and FIM motor analysis. During the patient's critical moment, the adoption of a motivational factor was able to generate greater involvement of this patient in the rehabilitation process. Studies have shown that treatment with VR was also able to provide motor-sensorial improvement [30] and function of upper limbs in patients with cerebrovascular accident [31] sequels. In another study, when used during phase II cardiac rehabilitation, VR was able to reduce time to reach target cardiac frequency during treatment, by adding motivation and distraction to the treatment [32].

The lower functional loss found in the VRG, might be associated with the higher level of energy when comparing to the patients in the CG in delta 1. With a better energy level, the required motor functions during the physiotherapeutic protocols, may be done with less restriction. These motor functions were performed in both groups, aiming at the same metabolic expenditure, as expected by the phase 1 cardiac rehabilitation program. However, in the VRG, besides the motor work, the involvement with the "virtual world" through interactive games generated the addition of a motivational factor that contributed to the physiotherapeutic rehabilitation program, assuring better functionality [33,34].

Although inserted in a postoperative rehabilitation program, there are intra and postoperative factors such as pain and the increase of anxiety that contribute to functional loss [8,10]. Pain was evaluated in patients from this study through NHP and has shown greater intensity in delta 1 in patients from both groups. However, it was lower in patients from VRG in all evaluation moments (delta 1, 2 and 3) when compared to the CG and this difference was statistically significant in delta 3, showing that patients from the VRG were hospital discharged with less pain intensity.

During hospital stay, the analgesic routine procedure was kept to all operated patients from both groups. No direct physiotherapeutic resource was used to reduce pain. We then could say that, as the patients from the VRG were trying to achieve a goal while playing a game, they may have reduced the psychosomatic effect of pain, participating more effectively in the rehabilitation process. Corroborating with this hypothesis, studies have shown that the use of VR is capable of providing distraction during physiotherapeutic approach during procedures that cause exacerbating pain, generating better results in physical movement and mobility [21]. VR was also able to reduce anxiety and the perception of pain in pediatric patients submitted to postoperative physiotherapy as they had a fun motivating element [35]. It also provided greater relieve of pain during the treatment of burned patients [36].

Although the patients from both groups presented similar function capacity on the hospital discharge day, the patients from the VRG showed a significant reduction in hospital stay. Such fact is clearly associated with lower pain intensity in the VRG on the hospital discharge day [6].

Besides earlier hospital discharge compared to patients from the CG, patients from the VRG had gone further on the six minute walk test, performed on the hospital discharge day. Greater walking capacity means greater cardiovascular condition [37]. This was demonstrated in these patients, confirming the validity and safety of VR as a rehabilitation tool. Benefits from the use of VR include improvement in the visual perception and gait rehabilitation process in diabetic patients [38].

The psychological effects of cardiac rehabilitation have been described so far as being weaker than those from the physical domain, though the physical domain effects may serve as base for the effects from the psychological domain [37]. When using VR as an auxiliary tool, we bind the motivational effect to the physical therapy, which generates greater therapeutic participation, which could explain the already mentioned results.

The results of the two domains (pain and energy level) analyzed show the functional improvement described by the FIM on the patients form the VRG on the 1st POD, because it is known that pain limits functional recovery [39].

When we analyze the emotional reaction, physical abilities and social interaction domains form the NHL, we notice a progressive improvement in the health profile with the time of treatment, without significant difference between groups, thus confirming the results from the literature that show the positive effect of cardiac rehabilitation during the postoperative period of cardiac surgery [37,40].

The results of the sample characterization found in this study show that it is a homogenous one, with no elderly adults, as there was no significant difference in either group that would characterize it. For most patients, it was their first experience with video games and even though they were adults, it did not seem to be a barrier; on the contrary, they were eager to learn something new, something that could help them recover sooner. The search for recovery and learning may have been influencing factors for a better social interaction of the patients from the VRG.

It is importantly to say that both groups underwent respiratory physiotherapy during the study. Thus, the better functional performance of the VRG could be associated with greater motivation for the performer and a better involvement in the treatment program achieved with the minimization of anxiety and fear that are often felt in the immediate postoperative period [40]. According to our results, we can speculate that the use of virtual reality, acting as a motivating factor to encourage the patient to perform the exercise, increases patients' self-esteem, providing a challenge to perform an action associated with a functional activity.

The positive effect of cardiac rehabilitation in post-cardiac surgery has been well documented [17,18]. Both groups demonstrated an increase in the motor FIM score and in the total FIM accordant with the progression of treatment.

However, despite the groups showed similar functional capacity on the day of hospital discharge, patients in the VRG presented a reduction in hospital length of stay due to to their improvement in functional capacity recovery in consequence of pain attenuation and greater level of energy what leads to a better functionality.

Moreover, despite the similarities in functionality between the groups from discharged individuals, patients allocated in VRG also demonstrated a greater 6MWD. Because it is the idealization of a new therapeutic approach, this finding suggests that although the functional impairment promoted by the surgical procedure, the treatment with the VR was able to provide greater therapeutic involvement during postoperative recovery.

CONCLUSIONS

The use of virtual reality for rehabilitation of patients subjected to cardiac surgery proved effective, providing greater functional independence, better energy levels, less pain and shorter hospitalization, as well as improving walking capacity of patients from the VRG.

It is also clear that at the end of cardiac rehabilitation phase I, the patient has not recovered all preoperative function and, therefore, it is essential to include these patients in cardiac rehabilitation programs phase II.

Funding

This work was supported by grants from the National Council for Scientific and Technological Development (Conselho Nacional de Desenvolvimento Científico e Tecnológico/ CNPq/ Brazil) and the Research Foundation of the State of Sergipe (Fundação de Apoio à Pesquisa e à Inovação Tecnológica do Estado de Sergipe/FAPITEC-SE).

Conflicting of interests declaration

There are no affiliations with any organization to any author's knowledge that has a direct interest in the subject matter discussed.

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