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Journal of Cardiovascular Diseases

ISSN 2831-3437

Research Article

Development Of Virtual Reality-Based Therapy Protocols For Cardiovascular Rehabilitation.

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Abstract

Due to its playful nature, virtual reality protocols (VR) is able to increase adherence in patients taking part in both for the treatment and prevention of cardiovascular diseases (CVD) and cardiovascular rehabilitation (CR). Despite all the positive and significant results proven by the aforementioned studies, the games used were commercial exergames, they were created for healthy people, and not intended to be used in cardiovascular rehabilitation (CR). Other several crucial aspects and limitations have emerged, as the costs of exergaming equipment can be prohibitive and some patients may struggle with adopting new technology, and these commercial solutions may not be sufficiently tailored to individuals' exercise needs. In this contexto, the aim of this study was to develop virtual reality (VR) protocols at different intensities and sports modaliteis that are specific to cardiac patients, while respecting the characteristics of the exercise performed during CR sessions. This manuscrips presents a whole protocol with 15 heating exercises, six diferents sports games protocols (judo, football, muay thai, volley, swimming and atletics) and the relaxing fase.

Keywords: Exergames, Heart Failure, Cardiac Rehabilitation, Exercise Therapy, Physical Activity, Adherence.

INTRODUCTION

The notorious importance of cardiovascular rehabilitation (CR), both for the treatment and prevention of cardiovascular diseases (CVD) and risk factors for the development of CVD, is already well established (Carvalho et al., 2020; Zang et al., 2024). In addition, studies have shown the benefits of frequent exercise in improving aerobic capacity, cardiovascular function and quality of life in these individuals, as well as reducing mortality (Hong et al., 2025; Mahmood et al. 2024),

Despite the many studies that underline the health benefits derived from performing physical exercise (Lavie et al. 2019), we have a huge numbers of physically inactive people Around the world (Bull et al. 2020) and a new study (McDonough, and Gao 2020) indicated that one of the main reasons for the lack of sufficient physical levels of the population is that they conceived it as a boring and a difficult task to perform (Rubio-Arias et al.,2024).

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 (Viera et al. 2023). In this context, virtual reality (VR) is a high-end user-computer interface involving real-time stimulation and interaction of an embedded subject through visual and auditory sensorial channels, based on a synthetic environment in which the subject feels to be presente (De Giogi et al., 2024). In addition, due to its playful nature, VR is able to increase adherence (Cruz et al., 2021) in patients taking part in CR. This exergames have been shown to promote acute hemodynamic responses similar to conventional CR in patients with heart disease, allowing these patients to also achieve heart rate reserve during their performance (Cruz et al., 2020).

Despite all the positive and significant results proven by the aforementioned studies, the games used were commercial games, i.e. games that were created for healthy people, and not intended to be used in CR, as pointed out by Cruz et al (2020). Other several crucial aspects and limitations have emerged, as the costs of exergaming equipment can be prohibitive and some patients may struggle with adopting

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Email: marianne.barbosa@fema.edu.br.
Received: 14-October-2025, Manuscript No. JOCD-5185 **; Editor Assigned:** 15-October-2025 **; Reviewed:** 30-October-2025, QC No. JOCD-5185 **;**
Published: 12-November-2025, **DOI:** 10.52338/jocd.2025.5185.
Citation: Marianne Penachini da Costa de Rezende Barbosa. Development Of Virtual Reality-Based Therapy Protocols For Cardiovascular Rehabilitation. Journal of Cardiovascular Diseases. 2025 November; 14(1). doi: 10.52338/jocd.2025.5185.

new technology, and these commercial solutions may not be sufficiently tailored to individuals' exercise needs (Blasco-Peris et al.,2025).

The main limitations of commercial games are the periods of inactivity during game changes, which makes them uncharacteristic of the type of continuous training that is most commonly used in CR. Therefore, creating CR games in which the therapist can manipulate the time interval between games, as well as the intensity of training, is extremely important in order to open up new horizons in this field.

Therefore, we hypothesize that the creation of protocols and the development of specific games for cardiac patients, the use of VRT will be safer, as it will provide better control of intensity, as well as promoting greater benefits for the physical state of this population. For this reason, the aim of this study was to develop VRT protocols at different intensities and sports modaliteis that are specific to cardiac patients, while respecting the characteristics of the exercise performed during CR sessions.

METHODOLOGY

Study design

These protocols will be reported in accordance with the Standard Protocol Items: Recommendations for Interventional Trials (SPIRIT) and this manuscript describes Stage I of a project whose ultimate goal is to develop a virtual reality game for cardiac patients, so that users can carry out a Home Cardiac Rehabilitation Program.

This study is being carried out at the Educational Foundation of the Municipality of Assis (FEMA) and at the Universidade Estadual Paulista, Júlio de Mesquita Filho (FCT-UNESP) in Presidente Prudente - São Paulo. The experimental procedure will be carried out in 3 stages: I- Development of VRT game protocols aimed at VRR of different intensities; II- Implementation of the protocols developed with patients who attend VRR, with the aim of evaluating the intensity of the protocols; III- Development of the specific virtual reality game based on the protocols created.

Participants

The participants in this study will consist of patients treated in the Cardiology Department of the Center for Studies and Care in Physiotherapy and Rehabilitation - CEAFiR of the Faculty of Sciences, Educational Foundation of the Municipality of Assis - FEMA and Technology, of the Universidade Estadual Paulista, Júlio de Mesquita Filho (FCT-UNESP) of Presidente Pdente - São Paulo.

Eligibility criteria include patients diagnosed with cardiovascular disease or risk factors who have been participating in a regular cardiovascular rehabilitation program for at least three months, over 18 years of age, regardless of gender, and with reported availability to perform the proposed protocol. Participants with comorbidities and/or acute signs or symptoms during regular sessions which prevent them from carrying out the experimental protocol, such as significant changes in balance due to not using a treadmill during the regular program, will be excluded from the study.

After the initial invitation, patients who are considered eligible will be informed about the procedures and objectives of the research, and if they accept, they will sign an informed consent form. All procedures were approved by the Institution's Research Ethics Committee (CAAE: 54443221.6.0000.8547).

Stage I - Drawing up protocols for VRT games aimed at CR of different intensities.

This manuscript describes the protocols, which are based on the recommendations of the National and International Guidelines for Cardiovascular Rehabilitation (Carvalho et al., 2020; Herdy et al., 2014). The guidelines state that a CR session consists of three phases: warm-up, conditioning and relaxation.

The warm-up lasts 15 minutes, where we develop a single model which will be applied in all the protocols developed. During this phase, the exercises are performed with the aim of progressively increasing intensity. The warm-up is described in **Table 1**.

Table 1. Heating

Warm-up exercises
1) Neck stretch: with the help of the hand, the player tilts the neck. - 3 sets of 15 seconds.
2) Lateral spine stretch: player crosses legs and with arm in maximum flexion tilts spine. - 3 sets of 15 seconds.
3) Shoulder stretch: player performs an adduction with the shoulder at 90º flexion and with the opposite hand pulls the arm towards the torso. - 3 sets of 15 seconds.
4) Triceps brachii stretch: the player flexes the shoulder and elbow and pulls the tip of the elbow back. - 3 sets of 15 seconds.
5) Hamstring and gluteal stretch: in uni podal position, the player will flex their knee and hip, then pull their leg up to the line of their abdomen. - 3 sets of 15 seconds.

6) Stretching the leg extensor muscles: in an orthostatic position, the player will flex their torso so that their fingertips touch their feet. - 3 sets of 15 seconds.
7) Stretching the triceps suralis: leg in front of the body, flex the knee, and the opposite leg remains extended. - 3 sets of 15 seconds.
8) Elbow flexion: Player in an orthostatic position, arms alongside the body, flexes the elbow to 90 degrees. - 3 sets of 10 repetitions.
9) Shoulder abduction: Player in standing position performs shoulder abduction. - 3 sets of 10 repetitions.
10) Plantar flexion: Player in orthostatic position performs plantar flexion. - 3 sets of 10 repetitions.
11) Knee flexion: Player in orthostatic position performs knee flexion. - 3 sets of 10 repetitions.
12) Hip flexion: Player in orthostatic position performs hip flexion. - 3 sets of 10 repetitions.
13) Hip abduction: Player in standing position performs hip abduction. - 3 sets of 10 repetitions.
14) Plantar flexion combined with elbow flexion. - 3 sets of 10 repetitions.
15) Jumping jack exercise: Player jumps while abducting the lower limbs and upper limbs. - Duration: 30 seconds.

The conditioning phase lasts 30 minutes, in which the intensity of exercise must be continuous, seeking to maintain the intensity or individual heart rate range stipulated. Protocols were created based on six sports: soccer, judo, muay thai, swimming, athletics and volleyball. As well as being based on the different sports, they were also based on different intensities (light 40-50% heart rate reserve; moderate 50-60% heart rate reserve and intense 60-70% heart rate reserve; where the heart rate reserve was calculated using the Karvonen formula). The protocols are shown in **Table 2**.

Table 2. Sports game protocols.

Modalidade	Intensidade Leve	Intensidade Moderada	Intensidade Alta
JUDO	1) Simulated grip, gripping the collar (hand on shoulder) and sleeve (hand on elbow) being D/E, as if gripping the judogui (training uniform). -Duration: 1 minute	1) Grab simulation: grab the collar and pull the opponent towards you. -Duration: 1 minute	1) Grab the collar of the opponent who is sitting down and pull up. -Duration: 1 minute
	2) Simulation of walking on the mat, side stepping D/E and stepping backwards and forwards (dragging the foot). -Duration: 1 minute	2) Simulation of how to walk on the mat - lateral stride D/E and stride backwards and forwards (fast stride). -Duration: 1 minute	2) Simulation of walking on the mat, side stepping D/E and stepping backwards and forwards and touching the floor at the end of each step (quick step). -Duration: 1 minute
	3) Simulation of the first ASHI HARAI blow (sweeping something). -Duration: 1 minute	3) Simulating the O GOSHI blow: hug your waist with one hand and hold your sleeve with the other, turning your body until your body is facing the other person. -Duration: 1 minute	3) Simulation of the KATA GURUMA blow: with one hand holding the sleeve, the other hand embraces the leg and lifts the person in line with their shoulders. -Duration: 1 minute
	4) Simulation of the OCHI GARI move (foot/leg bar). -Repetitions: 6 on each side Series: 2 times.	4) Simulation of the HARAI GOSHI blow: with a normal grip, extend one leg out to the side, blocking the other person's passage.	4) Simulation of the UKI WAZA blow: with a normal collar and sleeve grip, sit on the mat and with one leg stretched out block the person's passage.
	5) Fight simulation for 1 minute.	5) Fight simulation for 2 minute.	5) Fight simulation for 3 minute.

FOOTEBALL	1) Squat. -Duration: 1 minute	1) Squat with shoulder flexion. -Duration: 1 minute	1) Squat with jump and shoulder flexion. -Duration: 1 minute
	2) Lateral run from a central point to the RIGHT and then to the LEFT. At each end a ball appears for the player to catch. -Duration: 1 minute	2) Lateral run from a central point to the RIGHT and then to the LEFT. At each end a ball appears for the player to kick. -Duration: 1 minute	2) Lateral run from a central point to the RIGHT and then to the LEFT. At each end a ball appears for the player to catch or kick. -Duration: 1 minute
	3) Goalkeeper simulation: raise both arms upwards as if you were going to catch a ball (ball comes at the top and bottom). - 1 minute duration	3) Goalkeeper simulation: raise both arms upwards as if you were going to catch a ball (ball comes towards the left or right side). - 1 minute duration	3) Goalkeeper simulation: raise both arms as if you were going to catch a ball (ball comes in all directions). - 1 minute duration
	4) Striker simulation: A central ball will appear which the player must shoot at goal. - Duration: 1 minute	4) Striker simulation: A ball will appear on one of the sides and the player must shoot at goal. - Duration: 1 minute	4) Striker simulation: A ball will appear on the sides and at different heights which the player must shoot at goal. - Duration: 1 minute
	5) Simulated header: The ball comes towards the center and the player heads it towards goal. - Duration: 1 minute	5) Simulated header: The ball comes in from the left and right and the player heads it into the goal. - Duration: 1 minute	5) Simulated header: The ball comes in at a high height and the player has to jump to head it into the goal. - Duration: 1 minute
	6) Simulated throw-in: The player on the sideline throws the ball to a marked (central) spot. - Duration: 1 minute	6) Simulated throw-in: The player on the sideline throws the ball to a marked spot a long distance away (central). - Duration: 1 minute	6) Simulated throw-in: The player on the sideline throws the ball to a marked spot at a long distance (center and sides). - Duration: 1 minute
MUAY THAI	1) Punch forward alternating both hands. - Duration 1 minute.	1) Punch forward alternating both hands, counting progressively. - Duration 1 minute.	1) Straight punch with the left hand, then with the right hand and a cross punch with the left hand. - Duration 1 minute.
	2) Elbow with trunk rotation. - Duration 1 minute.	2) Front elbow kick with trunk rotation. - Duration: 1 minute.	2) Front kick with straight punch with left hand and then elbow with trunk rotation. - Duration: 1 minute.
	3) Cross punch to the ribs with both hands D / E. - Duration 1 minute.	3) Knee strike with straight punches. - Duration 1 minute.	3) Knee with a straight right hand punch, a cross with the left hand and then a straight right hand punch. - Duration 1 minute.
	4) Kneel forward, once with each leg, both sides D/E. - Duration: 1 minute.	4) Front kick, with straight punches (Jeb and Straight). - Duration: 1 minute.	4) Knee strike with 4 straight punches in a row with both hands, ending with a front kick. - Duration: 1 minute.
	5) Front kick, with arms at face level. - Duration 1 minute.	5) Front kick, straight punches and then knee strikes. - Duration 1 minute.	5) Front kick, followed by 4 straight punches with both hands, followed by cross punches and ending with a front kick. - Duration 1 minute.
VOLLEY	1) Passing/carrying the ball in a central direction (extending and flexing the arms above the line of the head). - Duration: 1 minute.	1) Passing/carrying the ball to the sides (extend and flex your arms above your head). - Duration: 1 minute.	1) Passing/carrying the ball in different directions (extending and flexing the arms above the head). - Duration: 1 minute.

VOLLEY	2) Blocking: in the standing position, the outstretched arms flex the shoulders until they reach the ball coming in the central direction. - Duration: 1 minute.	2) Blocking: in the standing position, the outstretched arms flex the shoulders until they hit the ball coming from the side. - Duration: 1 minute.	2) Blocking: in an orthostatic position, arms outstretched, jump and flex your shoulders until you hit the ball, which comes in different directions. - Duration: 1 minute.
	3) Reception: the player must receive the central ball with a dribble. - Duration: 1 minute.	3) Reception: the player must receive the ball coming in from the side with a stick. - Duration: 1 minute.	3) Reception: the player must receive the ball coming in from any direction with a dribble. - Duration: 1 minute.
	4) Attack: Alternating hands, the player hits the central balls that appear. - Duration: 1 minute.	4) Attack: Alternating hands, the player hits the side balls that appear. - Duration: 1 minute.	4) Attack: Jumping and alternating hands, the player will hit the balls that appear. - Duration: 1 minute.
	5) Mix of movements: The player will perform a sequence of the previous moves. The order will be announced on the screen. - Duration: 1 minute.	5) Mix of movements: The player will perform a sequence of the previous moves. The order will be announced on the screen. - Duration: 1 minute.	5) Mix of movements: The player will perform a sequence of the previous moves. The order will be announced on the screen. - Duration: 1 minute.
SWIMMING	1) Crawl (with both arms extended forward, rotate from bottom to top returning to the starting point). - Duration: 1 minute.	1) Crawl (with both arms extended forward, rotate from bottom to top, returning to the starting point). - Duration: 1 minute 30 seconds.	1) Crawl (com os dois braços estendido para frete, fazer rotação de baixo para cima retornando ao ponto inicial). - Duração 2 minutos.
	2) Backstroke (rotation of the arm from top to bottom, returning to the starting point). - Duration: 1 minute.	2) Backstroke (rotation of the arm from top to bottom, returning to the starting point). - Duration: 1 minute 30 seconds.	2) Backstroke (rotation of the arm from top to bottom, returning to the starting point). - Duration 2 minutes.
	3) With your legs extended, flex and extend your knees once on each side. - Duration: 1 minute.	3) With your legs extended, flex and extend your knees once on each side. - Duration: 1 minute 30 seconds.	3) With your legs extended, flex and extend your knees once on each side. - Duration: 2 minutes.
	4) Butterfly (rotation from bottom to top of arms together, and doing squats together). - Duration: 1 minute.	4) Butterfly (rotation from bottom to top of arms together, and doing squats together). - Duration: 1 minute 30 seconds.	4) Butterfly (rotation from bottom to top of arms together, and doing squats together). - Duration: 2 minutes.
	5) Crawl swimming with legs. - Duration 1 minute.	5) Crawl swimming with legs. -Duration 1 minute 30 seconds.	5) Crawl swimming with legs. - Duration 2 minutes.
ATHETICS	1) Simulate throwing a javelin. - Duration 1 minute.	1) Simulate throwing a javelin. - Duration 1 minute and 30 seconds.	1) Simulate throwing a javelin. - Duration 2 minutes.
	2) Athletic walk: walk on a line with one foot in front of the other. - Duration: 1 minute.	2) Athletic walk: walk on a line with one foot in front of the other. - Duration: 1 minute 30 seconds.	2) Athletic walk: walk on a line with one foot in front of the other. - Duration: 2 minutes.
	3) Walk in the woods movement, jumping upwards with one foot on the ground and the other leg bent. - Duration: 1 minute.	3) Walk in the woods movement, jumping upwards with one foot on the ground and the other leg bent. - Duration: 1 minute 30 seconds.	3) Walk in the woods, jump upwards with one foot on the ground and the other leg bent. - Duration: 2 minutes.
	4) 100m run: stationary run. - Duration 1 minute.	4) 100m run: stationary run. - Duration 1 minute 30 seconds.	4) 100m run: stationary run. - Duration 2 minute.
	5) Barrier jump simulation. - 1 minute duration.	5) Barrier jump simulation. - Duration 1 minute 30 seconds.	5) Barrier jump simulation. - 2 minute duration.

Finally, the relaxation phase lasts 5 minutes, with the aim of slowing down the cardiovascular system and ending the session.

CONCLUSION

This study will make it possible to determine the safety intensity of the individual virtual reality protocols proposed, with the aim of creating specific games for people with heart disease or risk factors.

Acknowledgments

We would like to thanks Fundação Educacional do Município de Assis (FEMA) for the financial supporting of the present research.

Conflicts of Interest

The authors declare no conflict of interest.

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