Chapter 98

Serious Game With Cycloergomerics Adapted For The Training Of Post-Stroke Hemiparetic Patients In Acute Phase: A Feasibility Study

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ABSTRACT
Cycloergometry associated with a Serious Game can contribute to the improvement of lower limb motor performance, aerobic capacity, balance, and in addition, increase motivation during therapy. This study is conducted to evaluate the feasibility of using adapted cycle ergometry associated with a serious game on hemiparetic patients due to stroke in the acute phase. It is a feasibility study with a cross-sectional design, with hospitalized patients aged 18 years or older and clinically stable. Pre-intervention: lower limb performance (Sit and Stand Test for five times) and functional mobility (Timed Up and Go Test) evaluated. A Likert scale was applied to verify the motivation, training ease performing, and the participants' perception of the resource's usefulness. The Serious Game was used on two consecutive days for 30 minutes each. Vital signs and perceived exertion (Borg Scale) were monitored during therapy. Sixty-five individuals, with a mean age of 62, 88 12, 23, participated in the research. Regarding motivation during the game, 98.5% of the participants reported feeling motivated during the activity. The resource was considered easy for 87.7% of the individuals, and 78.5% perceived its usefulness in therapy. There was no statistically significant difference in hemodynamic variables, demonstrating safety in the application of the game in the acute phase. The motivation, attention, engagement, and satisfaction with the use of the system during the sessions indicate a very interesting potential for use in this phase.

Keywords: Video Games, Exercise Therapy, Paresis, Stroke.

1 INTRODUCTION

Considered the second leading cause of death in the world, stroke is defined as a neurological dysfunction due to sudden vascular impairment, which can cause decreased functional capacity in its survivors (Avan et al, 2019). According to the World Health Organization, it is estimated that around the world, 15 million people are affected by stroke event annually (WHO, 2023). Brazil recorded in the year

2016, about 107,258 deaths from stroke, with ischemic stroke accounting for 60.2% of deaths (Bensenor et al, 2015).

As for functionality, in 2013 it was estimated that 560,000 people remained with post-stroke functional disability, such as deficits in motor control, balance, strength and mobility (Bensenor et al, 2015). It is observed that besides functional disability, stroke generates costs for the treatment of this population, who may require care and rehabilitation for a long period of time depending on the severity of the injury (CHRISTENSEN *et al*, 2009; DEWILDE et *al*, 2017; LOPEZ-BASTIDA *et al*, 2012). Given this, studies are needed that verify alternatives to complement conventional Physical Therapy treatment so that the rehabilitation process provides immersion, fun and engagement (MORRIS; WILLIAMS, 2009).

With the expansion of technology in the world and its development in several areas, its implementation in rehabilitation interventions has gained prominence in recent years due to its greater power of presence of the individual during the execution of the proposed activities (Mubin et al, 2020). Studies show that the implementation of games in the process of physical therapy rehabilitation are effective, as they can increase the therapy with possibilities of intensity control, adequate adjustments to the different degrees of impairment, provision of feedback, and adaptation to the individual needs of patients (CORBETTA et al., 2017; MUBIN et al., 2020; NOVELETTO et al., 2020; TĂUT et al., 2017).

Traditional games have been used by some studies as a resource in rehabilitation, however, because they are commercial games and not developed for therapeutic purposes, their application is restricted to a certain audience (TAY *et al.*, 2018; WÜEST; VAN DE LANGENBERG, 2013). To fill this gap, games developed specifically for rehabilitation have been an alternative to reduce some of these limitations, since they are designed for specific purposes while containing the fun contained in the games (NOVELETTO *et al.*, 2018).

The development of specific games, also called Serious Games (JS), allows the individual to have a motor learning process that provides greater adherence to neurofunctional rehabilitation by promoting immersion and fun while performing a specific task for a specific functional gain, unlike commercial games, which are less specific and have a higher level of complexity for the player (TAY *et al.*, 2018; WÜEST; LANGENBERG, 2013). In addition, the use of JS enables the individual to have a greater engagement in the rehabilitation process already in the acute phase, since some individuals may take longer to recover functional gains, being susceptible to demotivation and dropout throughout the process (TADDEO , 2009).

Another resource used is adapted cycloergometry (AC), which allows passive, active, and resisted exercises, improvement of lower limb functional capacity, trunk control, and gait speed (Campo et al., 2019). Considered a pre-deambulation rehabilitation method, cycling activity is tolerable in acute, subacute, or chronic post-stroke phases, where subjects perform by means of a simple activity, constant and cyclic lower limb movements that resemble walking (Ofori et al, 2019).

The Serious Game associated with adapted cycloergometry (JSCA)can contribute to the improvement of strength, neuromuscular control and performance of lower limbs as well as aerobic capacity and balance capacity, besides providing more safety and motivation for patients, allowing them to learn proper postures and functional skills due to its greater immersion power (FERRANTE et al., 2011; LEE, 2019; TANG et al., 2015; YANG et al., 2014).

In hospital settings, studies that evaluate the effectiveness of Serious Games in the acute phase of stroke are still scarce, as well as the use of adapted cycloergometry associated with them. Thus, testing the viability of using Serious Games in the acute phase of stroke is essential, since some individuals can take longer to recover functional gains, being susceptible to demotivation and giving up during the rehabilitation process. Thus, the use of JS can promote subsidies for a more effective participation of the patient in this phase, where functional gains should be stimulated early on to develop body awareness, postural control, and physical conditioning (Tăut et al, 2017).

It is observed that in addition to functional disability, stroke generates costs for the treatment of this population, who may require care and rehabilitation for a long period of time depending on the severity of the injury (CHRISTENSEN *et al.*, 2009; DEWILDE *et al.*, 2017; LOPEZ-BASTIDA *et al.*, 2012). Given this, studies are needed that verify alternatives to complement conventional Physical Therapy treatment so that the rehabilitation process provides immersion, fun and engagement (MORRIS; WILLIAMS, 2009).

Therefore, for this study, a JSCA was developed with the objective of evaluating the feasibility and safety of a treatment approach in hemiparetic post-stroke patients in the hospital phase.

2 METHODS

This is a feasibility study with a cross-sectional design, carried out between July and October 2021. Approved by the Ethics Committee on Research Involving Human Beings of Hospital Municipal São José (HMSJ) under opinion number 4702466 (CAAE: 45021021.8.0000.5362). The sample consisted of patients admitted to the stroke unit (UAVC) of a public hospital in the city of Joinville, who agreed to participate in the research and met the inclusion criteria: diagnosis of stroke, clinically stable; age range equal to or greater than 18 years; who were able to adopt independent bipedestation, with a score on the functional category gait scale (FAC) greater than or equal to 2. Among the exclusion criteria were: patients who presented hemiparesis due to other pathologies as well as hemiplegic patients; patients with a Rankin scale score higher than 2; patients with a history of previous Acute Myocardial Infarction, as well as decompensated congestive heart failure; patients with severe visual and/or auditory impairment; uncooperative patients and/or with severe cognitive deficit.

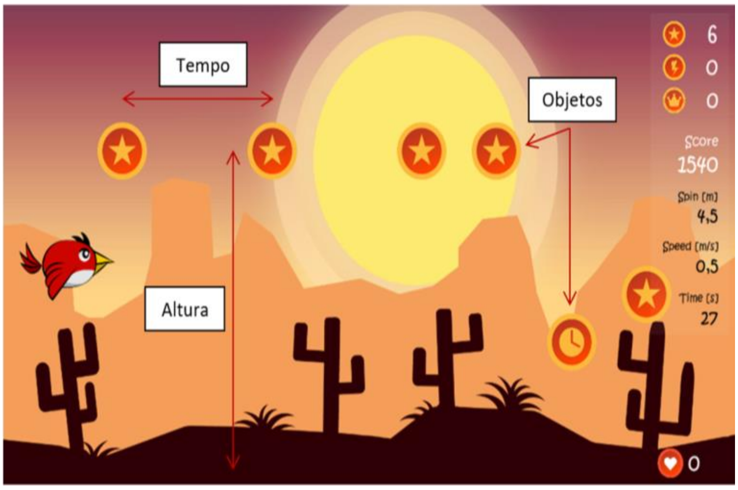
The participants and/or family members were informed and oriented about the procedures used in this research, as well as its objectives, benefits and risks, in accordance with the resolution CNS (National Health Council) 466 of December 12, 2012. After agreeing to participate in the research, everyone signed the Informed Consent Form (ICF).

The functional capacity of the individuals was evaluated through the Timed Up and Go Test (TUGT) and the Five Times Sit and Stand Test (5xSTS). The TUGT is one of the most used tests to assess functional mobility in post-stroke patients due to its test-retest reliability, besides being a quick and easy-to-apply test (Yu et al, 2021). To perform the test, the individual was instructed to get up from a chair with an arm and seat height of 44-47 cm, walk for 3 meters, turn around, return to the chair again, and sit down, while the professional quantified the total time in which the task was performed (Yu et al, 2021). The 5xSTS aims to evaluate the functional performance of the lower limbs. It is performed with the patient seated on a chair, without support for the upper limbs, instructed to cross their arms over their shoulders and sit down and stand up five times on the chair as fast as they can, and the time was recorded in seconds (Mong et al, 2010). The subjects were familiarized with the tests and clarified about their objectives.

For the analysis of acceptance and perception of individuals about the therapeutic modalities offered in the study, the application of a Likert-type scale was included in the post-intervention period, thus obtaining information about the acceptability of the therapy, enjoyment, ease of use, and perceived usefulness of the intervention. The questions consisted of: Did you feel motivated while performing the activity? Was it easy for you to perform the proposed activity? Can you perceive the usefulness of this activity in your recovery? Scores ranged from 1 (strongly disagree) to 5 (strongly agree).

The JSCA developed is called *goBit-bike*, whose objective is to control a character to collect objects that are presented in the game scenario. The location where the objects appear on the screen are defined by the physical therapist according to the therapeutic objective of the session. The character, a bird named *Bit*, moves vertically based on the spinning speed of the cycle ergometer. The faster the spinning speed, the higher the bird's flight. The speed is measured based on data obtained from a magnetic sensor (hall-effect sensor) is a set of four neodymium magnets attached appropriately to the pedal shaft. A heart rate sensor is used to monitor the patient before and after the session. The data generated is processed in an Arduino microcontrolled system and sent to the computer to control the game. JS *goBit-bike* is a 2D game and was developed using *Unity* software, specific for game programming. The visual aspects of the game are simple and focus the patient on the task of collecting the objects that move in the direction of the bird, which are related to the therapeutic goal. The CA and the screen with the parameters used in the therapeutic *setup* are shown in Figure 1 (A and B).

A) Adapted Cycloergometer B) Screen with parameters of the JS therapeutic *setup*



Source: The authors (2023)

As it was developed especially for the rehabilitation of hemiparetic patients, by a multiprofessional team, JS allowed the adaptation of the exercises with more safety and efficacy, combining the diverse knowledge. The risks of these procedures for all participants were low, and the risk of falling was minimized by the constant presence of the therapist beside the individual offering support if necessary. The individuals were trained during two consecutive days, each session lasting 30 minutes. The group had a training program with cycloergometry for LL in sitting position with trunk and upper limbs support, in addition to their standard multidisciplinary care, orientation about the stroke, encouragement to mobilization out of bed, training of postural changes and transfers, gait and balance training.

During the sessions, participants remained with their HR and SpO2 signals monitored by the therapist throughout the activity via finger Oximetry. The safety of the application was assessed by monitoring any adverse events. Fatigue ratings before and after each session using BORG's rating of perceived exertion (rating 6-20). Hemodynamic criteria defined in the multicenter study of early mobilization after acute stroke, called the AVERT- A Very Early Rehabilitation Trial after stroke (AVERT TRIAL COLLABORATION GROUP, 2015), were used to perform the activity. Activity would be stopped in case of: Systolic BP less than 110 mmHg or greater than 220 mmHg; SpO2 less than 92%; HR less than 40 or greater than 110 beats per minute (b.p.m.); Body temperature greater than 38.5°C; BORG scale score greater than 6.

3 DATA ANALYSIS

Data were tabulated and analyzed using the statistical *software Statistical Package for the Social Sciences* (SPSS) version *20.0* for *Windows.* The parameters were presented by descriptive measures such as mean and standard deviation for parametric data and frequency distribution with absolute values and percentages for non-parametric data. *Spearmann*'s correlation analysis was used to verify the association between the functional capacity tests. The significance level used was 5% ($p<0.05$).

4 RESULTS

A total of 65 post-stroke individuals in the acute phase were included in the research, with a mean age of 62.88±12.23 years. There was a prevalence of males with 58%. From the total number of participants, four people were evaluated for a pilot group and 61 were later included in the study. There were no dropouts throughout the research.

It was observed a predominance of white ethnicity with 84.6% of the cases. Other important data were the marital status: 50.8% married, low level of education where only 15.6% had finished high school and 50.8% had incomplete elementary school; professional status: 52.3% retired.

Table 1 shows the sociodemographic variables and clinical profile of the participants.

Table 1: Sociodemographic and clinical variables of the participants.

		n = 65	
Variables	**Categories/Unit**		**f (%)**
Sex			
	Female	-	27 (41, 5)
	Male	-	38 (58, 5)
Age			
	Years complete	62, 88 12, 23	-
Hemiparesis Side			
	Right	-	16 (24, 6)
	Left	-	12 (18, 5)
	No apparent deficit	-	37 (56, 9)
Ethnicity*			
	White	-	55 (84, 6)
	Black	-	09 (13, 8)
	Yellow	-	01 (1, 50)
	Grizzly	-	00 (0, 00)
Marital Status			

	Single	-	08 (12,3)
	Married	-	33 (50,8)
	Widower	-	10 (15, 4)
	Divorced	-	14 (21, 5)
Level of Education			
	Illiterate	-	04 (06, 2)
	Fundamental Incomplete	-	33 (50, 8)
	Elementary School Complete	-	05 (07, 7)
	Incomplete High School	-	09 (13, 8)
	High School Complete	-	10 (15, 4)
	Higher Education Incomplete	-	02 (03, 1)
	High School Complete	-	02 (03, 1)
Previous stroke without deficit			
	Yes	-	23 (35, 4)
	No	-	45 (69, 2)
Smoking			
	Yes	-	18 (27, 7)
	No	-	27 (41, 5)
	Previous	-	20 (30, 8)
Physical Activity			
	Yes	-	20 (30, 8)
	No	-	45 (69, 2)

Professional Status			
	Active	-	23(35, 4)
	On leave/medical sickness	-	02 (03,1)
	Retired	-	34(52, 3)
	Inactive	-	06 (09, 2)
Heredity			
	Yes	-	27 (41, 5)
	No	-	38 (58, 5)
Type of stroke			
	Ischemic	-	57 (87, 7)
	Hemorrhagic	-	04 (06, 2)
	AIT	-	04 (06, 2)
Alcoholism			
	Yes	-	05 (07, 7)
	No	-	45 (69, 2)
	Previous	-	15 (23, 1)
Wandering			
	With 1 person support	-	09 (13, 8)
	With supervision	-	15 (23, 1)
	Independent on flat surfaces	-	15 (23, 1)
	Independent on any surface	-	26 (40, 0)

Legend: mean; dp: standard deviation; f: absolute frequencies. %: percentage frequencies of the variable analyzed within the group. *Self-reported - ethnicity categories: according to IBGE classification.

All participants were admitted to the Stroke Unit and had a confirmed diagnosis of stroke or TIA; among the types, ischemic stroke led with 88%, followed by hemorrhagic stroke 6% and TIA 6%. As modifiable risk factors for stroke, active smoking appears in 27.7% of the cases and previous smokers in 30.8% of the cases; active alcoholism had a lower percentage with 7.7% and former alcoholics in 23.1% of the cases. A low level of physical activity was observed, since only 30.8% of the individuals reported performing some type of activity, where 50% of these with a frequency of 5 times a week.

Regarding ictus-related dysfunctions, 28 out of 65 individuals had hemiparesis. A total of 36% of the cases required assistance or supervision to ambulate.

Table 2 shows the results of the evaluation tests of the clinical-functional characteristics of the individuals in the study. It is observed a great variation between the minimum and maximum values in the tests, since some patients had better functional capacity and others had greater motor deficits that prolonged the execution of the evaluation. For this, a cutoff point was made for each test, where 49 patients took more than 12 seconds to perform the 5xSTS, indicating lower limb muscle weakness, and 28 patients took more than 14 seconds to finish the TUGT associated with a higher risk of falling.

Table 2 - Variables of the applied tests:$_{5x}$ STS and TUGT.

Variables		Minimum	Maximum	Cut-off point*
5xSTS (seconds)	15, 54 ± 5, 47	7, 52	37, 16	.> 12s= 49
TUGT (seconds)	20, 38 ± 23, 77	6, 95	158, 0	.> 14s= 28

Legend: x: mean; dp: standard deviation; 5xSTS:: 5 Times Sit and Stand Test; TUGT: Timed Up and Go Test
*Cut-off point: Indicative values of low functional performance (5xSTS) and high risk of falling (TUGT).

When performing the association between the functional tests a strong correlation was observed between the FAC and the TUGT. The 5xSTS showed moderate correlation with the TSL and the FAC (Table 3).

Table 3 - Correlation between the tests applied and the gait functional category scale: 5xSTS, TUGT and FAC.

Variables	r	p value
FAC X TUGT	-0, 74	0, 000*
FAC X STS $_{5x}$	-0, 61	0, 000*
TUGT X STS$_{5x}$	0, 75	0, 000*

Legend: FAC: Functional Ambulation Classification; 5xSTS : 5 Times Sit and Stand Test; TUGT: Timed Up and Go Test;
Level of significance: $p<0.05$; r: Spearmann correlation

The JS variables showed no significant variations comparing the first session with the second session, both in scores and in distance and average speed achieved (Table 4).

Table 4- Presentation of the averages of the JS variables: Score, distance traveled, and speed achieved.

Variables		Minimum	Maximum	p-value
Session 1 Score	23908, 37 ± 7703, 26	13796, 67	64183, 33	0, 833
Session 2 Score	23696, 51 ± 3695, 05	13143, 33	31056, 67	
Session distance 1	40, 02 ± 12, 56	14, 23	95, 60	0, 231
Session 2 distance	41, 36 ± 11, 34	15, 07	71, 53	
Average speed 1	0, 28 ± 0, 08	0, 10	0, 60	1, 000
Average speed 2	0, 28 ± 0, 66	0, 10	0, 50	

Legend: Significance level: $p<0.05$; : mean; SD: standard deviation; Distance traveled in meters in session 1 and session 2; Average speed in meters per second in session 1 and session 2.

In relation to the Likert scale, the motivational factor stands out, in which 98.5% of the participants reported feeling motivated during the activity. The perceptions of the participants did not differ between men and women. The results of the Likert scale can be seen in table 5.

Table 5: Perception of the participants regarding the proposed activity with JS.

	n =65	**f (%)**
Was it easy to accomplish the task?		
	Indifferent	1 (1, 5)
	Agree Partially	7 (10, 8)
	Totally agree	57 (87, 7)
Did you feel Motivated during the activity?		
	Indifferent	1(1, 5)
	Totally agree	64 (98, 5)
Can you see the point?		
	Indifferent	11 (16, 9)
	Agree Partially	3(4, 6)
	Totally agree	51(78, 5)

Legend: f: absolute frequencies. %: percentage frequencies of the variable analyzed within the group.

Other variables analyzed were the SSVV during the intervals of the series. Table 6 presents the mean and standard deviation values of the SSVV and the analysis of the statistical difference between the initial and final values of the session.

Table 6- Presentation of the averages of the *monitoring* variables

Variables	**D$_1$** ±dp	**p** value	**D$_2$** ±dp	**p** value
WFP$_0$	109, 8±22, 9	0, 281	110, 34±16, 0	0, 116
WFP$_1$	110, 1±16, 1		107, 30±18, 3	
SpO2$_0$	96, 8±1, 9	0, 894	96, 7±1, 8	0, 723
SpO2$_1$	96, 7±1, 4		96, 6 ±1, 7	
FC$_0$	77, 4 ±15, 8	0, 119	79, 1± 16, 8	0, 221
FC$_1$	81, 0 ± 15, 1		81, 0±15, 0	
BORG$_0$	0,5±0,9	0,000	0, 7±1, 1	0,000
BORG$_1$	*1, 9±1, 4*		*1, 6±1, 4*	

Key: MAP_0 : Initial mean arterial pressure; MAP_1: : Final mean arterial pressure; $SpO2_0$: Initial partial oxygen saturation; $SpO2_1$: Final partial oxygen saturation; HR_0 : Initial heart rate; HR_1 : Final heart rate; $BORG_0$: Initial Borg scale; BORG : Final Borg scale $_1$

It can be observed that there was no statistically significant difference in hemodynamic variables. The assessment of perceived exertion by the BORG scale was the only variable that showed a statistically significant difference.

5 DISCUSSION

The research aimed to verify the feasibility of using a JSCA in patients in the acute post-stroke phase and to analyze the safety level of this practice.

About 57% of the individuals had no apparent motor impairment after the stroke, although 60% of the total sample had gait deficits, requiring assistance or supervision to ambulate. This fact may be correlated to previous gait deficits of these individuals (previous stroke) and aging factors (Yu et al, 2021). This gait difficulty may also be associated with poor lower limb functional performance in this study, as assessed by means of the five-time sit and stand test (5xSTS). Our sample obtained an average of 15.5 ±5.5 seconds to perform the test, values higher than the cut-off point for healthy elderly and stroke patients that is estimated at 12 seconds (Mong et al, 2010).

The performance of the lower limbs also affects functional mobility, since the test that evaluates it (TUGT) requires the ability to sit and get up from a chair. In this research it was observed that the mean time to perform the TUGT (20.38 ±23.77) was higher compared to what studies consider as a cutoff point (10 seconds for normal adults) and although there is no consensus on an estimated result for post-stroke individuals, some authors cite 14 seconds as a predisposition to falls (Hollands et el., 2010). The TUGT is a complex test because it requires a great deal of postural control to stand up, walk, go around an obstacle and return to the starting point, requiring more cognitive resources. This influence of one test over the other can be observed through the correlation found between them. When an individual takes a longer time to sit down and get up from a chair, this can increase the time it takes to perform the TUGT. Moreover, individuals who need more assistance in walking will probably also have longer times in these tests.

An important aspect that JSCA "Go bitbird" presents in its platform is the possibility for the individual to have an immediate notion about their performance in the game, which is through scores, distance and speed traveled, called outcome knowledge (Levin & Demers, 2021). Outcome knowledge is the basis of biofeedback, inducing a change in behavior by providing quantitative information of the player's performance. In addition, individuals primarily used vision to determine the speed of the pedal stroke and thus achieve the goal of the game which was to hit the target. The most commonly used feedback channel is vision, followed by hearing alone or in combination with vision, while kinesthetic feedback is much rarer (Skvortsov et al, 2021).

Also, the JS developed offers several auditory and visual stimuli, important for rehabilitation (Levin & Demers, 2021), and allows for customization according to the patient's preference and the criteria chosen by the therapist for the session, such as frequency, intensity, time, and progression. The combination of visual and auditory stimuli, with art, artistic styles, brightness, shape, and colors enrich the sensory experience making the activity more attractive (Pereira et al, 2021). In view of the aspects discussed about the benefits of game therapy in neurological patients, we conclude that it is not just a random activity to entertain the individual. The professional is no longer focused, i.e., he stops providing solutions during therapy, letting the patient explore the environment and seek the resolution of the challenge imposed independently. Moreover, the therapist uses clinical criteria to choose the games, and these criteria must be based on the assessment.

Few studies are found using individuals in the subacute and acute phase post stroke, among these, research demonstrates safety and feasibility of JS in functional improvement in the subacute phase (Xu et al, 2021., Laffont et al, 2019). One of them concluded that although JS does not replace conventional rehabilitation and does not show differences between the groups studied, when analyzing only individuals at 30 days post-ictal, it was observed that JS achieved greater efficiency in functional improvement when compared to conventional rehabilitation (Laffont et al, 2019). The low number of studies with individuals in the acute phase is also noticed with respect to conventional physical therapy rehabilitation. A randomized study with patients in the acute post-stroke phase hospitalized in a stroke unit observed that training with a cycloergometer associated with conventional physical therapy for five consecutive days obtained positive results in muscle control and activation, in addition to improving gait speed, lower limb strength, balance, and functionality (Pinheiro et al, 2021).

During the execution of the JS of this study, 87.7% agreed that the task was easy to be done and that it held their attention during the whole therapy time. With the inclusion of the Serious Games, the activity can reach many repetitions, positively influencing for the neuroplasticity process, without making the activity monotonous and boring, thus obtaining a greater involvement of the subject with the rehabilitation process (Sulfikar et al, 2021). We can reinforce this in the results obtained through the Likert scale of this study, where approximately 99% of the subjects felt motivated during the execution of the therapy. When the individuals were asked if they could perceive the usefulness of the game in the recovery process, 78.5% agreed positively.

As often described, the rehabilitation process is long when it comes to stroke. Many techniques can be used in order to respect the individuality of each patient. Over time, therapy can become monotonous, and it is important to use alternatives that promote motivation, engagement, and satisfaction. These aspects are important to maintain adherence to treatment and promote greater functional recovery (KLEIM; JONES, 2008; ROHRBACH; CHICKLIS; LEVAC, 2019; SUNDERLAND; TUKE, 2005). Thus, it cannot be denied that JS are a promising alternative and an important tool.

It is notable that games can ease the boredom of very long and tiring, yet necessary rehabilitation sessions to achieve goals. However, it is important not to forget the therapeutic aspect of the game. For this the clinician must direct its use, seeking to unite the characteristics of the games with the individual characteristics of each patient (MUBIN *et al.*, 2020).

Regarding the safety of using the game in acute patients, it can be observed through the vital signs, that there were no negative changes between the beginning and the end of the session. The *American College of Sports Medicine* recommends light to moderate intensity exercise in post-stroke individuals, with training HR between 40-70% of predicted maximum or Borg scale score from mild to strong (Williams & Wilkins, 2017). In this study, the Borg had a significant difference, showing that between the beginning and end of the session, individuals were more fatigued, but within the normal range on the Borg scale.

Currently, the recommendation guidelines for post-stroke aerobic exercise report that it is not indicated to start training if the individual has a systolic BP > 200 mmHg at rest and diastolic BP > 110 mmHg (Williams & Wilkins, 2017). Although it is common after stroke for resting BP to be elevated, the aforementioned cut-off points assist in obtaining a safe parameter during training. On both days of play, patients maintained a mean BP within the guidelines' recommendation, with no negative variations. Although this study is not aimed at aerobic training, the aforementioned recommendations help to ensure the safety of the research, especially because it deals with the acute phase of stroke.

A limitation of the study was the small number of sessions, although this deliberate design was enough to observe very positive impressions about the feasibility and safety of the technique, since no patient had any complaint and no complications were observed during or after the procedures. Since this was a feasibility study with two sessions, it was not possible to see the evolution of the patients through the scores and variables of the serious game. However, because it brings knowledge of results, the JS parameters and the scores in the game can be used to evaluate the evolution of the patient in future studies with more sessions, besides being able to correlate its data with scales already used for motor evaluation.

Regarding the profile of the patients included in the sample, there were also limitations, since in general they presented a good functional condition, despite the clinical instability inherent to the recovery phase. Regarding the equipment used, we observed instability of the cycloergometer during the execution of the game, which interfered with the pedaling speed.

6 CONCLUSION

This feasibility and safety study with a biomedical system involving a JSCA for acute post-stroke patients proved to be a promising and safe technique. The motivation, attention, engagement, and satisfaction with the use of the system during the sessions indicate a very interesting potential for use in this phase. New therapeutic resources that complement conventional physical therapy are welcome, especially in this period of hospitalization, where clinical instability often limits the rehabilitation process. However, a simple and motivating therapeutic approach can be easily integrated to the usual procedures, generating more pleasure during the service and increasing compliance to the rehabilitation process, often long and painful for patients and families.

The authors suggest the development of further research using Serious Games in the acute phase of stroke, with a greater number of sessions and longer training time, monitoring of vital signs, as well as evaluating the motivation and satisfaction of individuals facing this technique that combines conventional therapy with technology.

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