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Research Article

Telerehabilitation Through a Game Platform to Promote Physical Activity for Women With Breast Cancer

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Introduction: Cancer is the main public health problem in the world. One possibility for maintaining physical activity and promoting health is through telerehabilitation.
Objectives: To analyze the effect of virtual reality (VR) training on the variables: rating of perceived exertion (RPE) and heart rate (HR) in breast cancer patients.
Methods: Thirty women with breast cancer participated in this study. For healthy controls, 28 women participated, with similar ages to the cancer group. The participants performed VR training, always guided by the researcher. There were ten intervention sessions, using the game MoveHero. The RPE and HR were assessed at four moments (before the intervention and after each of the three songs), and the Brunel mood scale (BRUMS) was applied on the first, fifth, and tenth days.
Results: HR significantly increased between the assessments before and after the interventions on all days, except for the eighth day. There was a significant increase in the HR from the first to fourth days ($p = 0.033$) and from the first to ninth days ($p = 0.005$). Both groups presented significantly increased RPE values at all four moments ($p < 0.001$), while within days, the difference was significant from the first to fourth days ($p = 0.006$), the first to fifth days ($p = 0.049$), and the first to ninth days ($p = 0.056$).
Conclusion: The participants with breast cancer showed increases in RPE and HR during interventions, even though the difficulty of the game increased, providing evidence of improvements in their metabolic capacity.

Trial Registration: ClinicalTrials.gov identifier: NCT05530876

Keywords: breast cancer; home telerehabilitation; virtual reality

1. Introduction

Physical activity has been recognized as a fundamental pillar during breast cancer treatment [1]. Performing regular physical activity not only improves cardiovascular health, muscle strength, and overall physical function but also plays a key role in alleviating treatment-related side effects, such as fatigue, anxiety, and depression [2]. Additionally, exercise has been shown to improve immune function, promoting better tolerance to treatments and reducing the risk of disease recurrence [3, 4]. Physical activity improves muscle strength, flexibility, and overall well-being. In addition, engaging in regular physical activity can significantly alleviate fatigue, reduce the risk of lymphedema, and promote cardiovascular health, factors that are particularly pertinent for breast cancer survivors [5].

In order to promote physical activity [6], the use of new technologies has been growing, such as virtual reality (VR) [7]. VR fosters a sense of enjoyment and accomplishment as practitioners achieve various virtual challenges while distracting patients from potential discomfort during exercise [8]. These VR experiences allow individuals to participate in tailored exercise routines and therapeutic activities in interactive virtual environments [9]. These might be advantages for patients who do not adhere to conventional exercises of different intensities, such as running or walking.

Additionally, the integration of VR with telerehabilitation has been a game changer in the healthcare landscape, particularly when in-person therapies face limitations [10]. With VR-assisted telerehabilitation, patients can access guided rehabilitation sessions remotely, bridging the gap between healthcare professionals and those in need of care [11]. This approach not only enhances convenience but also enables continuous monitoring of progress and provides timely feedback from healthcare providers [12]. The application of VR in the telerehabilitation of cancer patients has beneficial effects by reducing anxiety and fatigue, while improving functionality [13]. Additionally, it provides equitable access to individuals who face geographic, physical, or economic limitations in reaching health services [14].

As the world of VR and telerehabilitation continues to evolve, research in this field demonstrates immense promise in advancing the field of rehabilitation for breast cancer patients. By harnessing the potential of VR and its seamless integration with physical activity, healthcare professionals can unlock numerous possibilities, empowering individuals with breast cancer to embark on a transformative journey of recovery, resilience, and renewed hope [15].

Considering the above, we designed a proof-of-concept protocol with breast cancer individuals and a control group (individuals without breast cancer) to test a VR software platform remotely, created with a game that enables the rehabilitation team to manage physical activity intensity [16]. Thus, we analyzed the influence of the game platform application considering the effect of physical activity on the rating of perceived exertion (RPE) and heart rate (HR), as well as on different mood states.

We hypothesized that all participants would be able to participate safely in the trial, with an increase in RPE and HR with practice. However, considering the difficulties that breast cancer individuals can have when moving their arms, we hypothesized that the control group would present lower RPE and HR during the game. Furthermore, the game was expected to enhance the mood of individuals with breast cancer, mitigating the emotional impact of the disease.

If the hypotheses are confirmed, the results of this study will be relevant for the use of telerehabilitation as a complementary possibility to provide improvement in metabolic capacity in individuals with breast cancer.

2. Materials and Methods

This is a nonrandomized longitudinal clinical trial. This study was carried out remotely, through telerehabilitation, with the support of the Clínica Hope Fisioterapia e Estética, which has its headquarters and the venue used in the city of Juiz de Fora, in the state of Minas Gerais, Brazil.

The study included 30 women diagnosed with breast cancer, previously confirmed by a specialist doctor, who attended physiotherapy at the Hope Fisioterapia e Aesthetics clinic in the city of Juiz de Fora, MG, and authorized by the owners. For the control group, 28 women who had never been diagnosed with any type of cancer were selected, matched by age with the group of women diagnosed with breast cancer.

All participants were informed about the objectives and procedures of the study and signed the free and informed consent (FIC) form. The study was approved by the Research Ethics Committee (CEP) of the Federal University of São Paulo (UNIFESP) under No. CAAE: 33293720.9.0000.5505.

The study included women over 18 years of age, diagnosed with breast cancer within a maximum of 5 years, who agreed to participate in the research and showed understanding compatible with the execution of the procedures. The exclusion criteria were women who had neurological diseases (infectious diseases, spinal cord injuries, epilepsy) or orthopedic diseases (orthopedic deformities, muscle strains, sprains, dislocations, fractures, and pain conditions), during the period of the study; an inability to play computer games due to visual, motor (fatigue, deformity, or muscle weakness), or motivational limitations, or difficulty understanding simple commands; metal implants in the skull; the use of hearing aids; and the use of anticonvulsant drugs or muscle relaxants.

In total, 30 women diagnosed with breast cancer were selected to analyze the effect on motor performance, pain, perception of exertion, and HR in the intervention using VR.

In the cancer group (CG), ten sessions were administered (two sessions per week), while in the control group, only one session was administered. Initially, the researcher contacted potential participants via telephone to invite them to participate and, if accepted, the first instructions were given, the procedures and objectives of the study were explained, the FIC form was sent via Google forms, and the participant was taught the procedure for capturing HR. Participants were instructed to place their index finger and middle finger stretched over the wrist, just below the base of the thumb, to identify the pulse, which was recorded for 1 min on the clock. The bpm was determined by the number of heartbeats in that time. After agreeing to participate and signing the consent form, a convenient day and time to start the intervention was scheduled. On the first day, the following information was collected through online forms: age, sex, corresponding phase of treatment (such as chemotherapy, initial diagnosis, complications, and diagnosis of recurrence), length of stay, associated diseases, medications in use, education, presence of lymphedema, peripheral neuropathy, and side effects by cancer. The Borg perception of exertion questionnaire was applied.

Next, VR training began, consisting of 10 days in total. Every day three phases of the game were played. Each phase lasted up to 5 min and could be ended earlier if the participant made five consecutive errors. If the participant reached the pre-defined scores, they moved on to the next phase; when this did not happen, the phase was repeated until the score was reached; however, the limit of only three phases per day was respected, even if the phases were repeated. The HR was recorded every day, 10 min before carrying out the tasks in the VR environment (at rest, sitting), and between each phase of the VR game (MoveHero—Figure 1) together with application of the Borg scale. The BRUMS form was applied pre- and postintervention on Days 1, 5, and 10. The control group played the three phases of the game, respecting the same rules as the CG and also answered the same questionnaire and scale, but only completed one session.

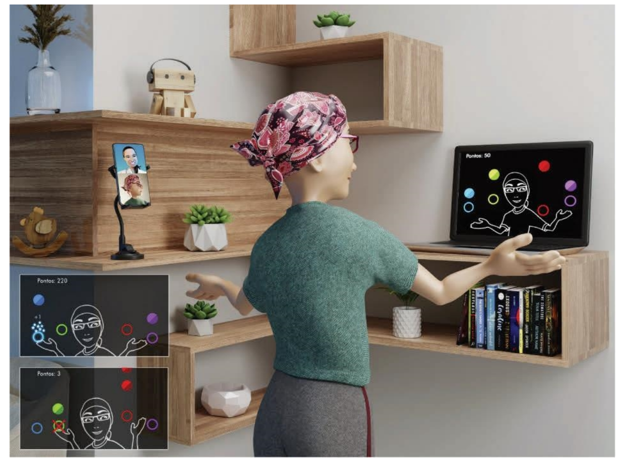

Figure 1: Task performed in MoveHero software.

2.1. Data Analysis. The continuous independent variable was submitted to the t test (age), and the categorical variables were submitted to the chi-square test.

The dependent variables used were the score on the RPE, Brunel mood scale (BRUMS), and HR. The dependent variables of BRUMS were submitted to a 3 (days: first, fifth, and tenth) by 2 (moments: before, after) within-factor multiple analysis of variance (MANOVA). The dependent variables of RPE were submitted to a 10 (days: first to tenth) by 4 (moments: baseline [Mo0], after first match [Mo1], after second match [Mo2], after third match [Mo3]) within-factor MANOVA. The dependent variables of HR were submitted to a 10 (days: first to tenth) by 2 (moments: before, after) within-factor MANOVA. The least significant difference (LSD) was used as a post hoc test. The partial eta-squared (η^2p) was reported to measure the effect size and interpreted as small (effect size > 0.01), medium (effect size > 0.06), or large (effect size > 0.14) (Lakens, 2013). We also reported the observed power (op). To assess the between-group factor (BC and CG) in the first assessment, a t test for independent variables was used. Values of $p < 0.05$ were considered significant. The statistical package used was the Statistical Package for Social Sciences (SPSS; IBM, Chicago, Illinois, USA), Version 28.0.

3. Results

A total of 58 women participated in this study (30 with breast cancer; 28 healthy controls). The participants' characteristics are presented in Table 1.

3.1. BRUMS. There were main effects for days regarding tension [$F_{2,30} = 1.15$, $p = 0.031$, $\eta^2 p = 0.24$, op = 0.63], vigor [$F_{2,30} = 5.40$, $p = 0.044$, $\eta^2 p = 0.21$, op = 0.60], confusion [$F_{2,30} = 0.77$, $p = 0.031$, $\eta^2 p = 0.23$, op = 0.64], and total [$F_{2,30} = 0.42$, $p = 0.021$, $\eta^2 p = 0.23$, op = 0.71]. We also found main effects for moments regarding tension [$F_{1,15} = 1.67$, $p = 0.011$, $\eta^2 p = 0.37$, op = 0.77], depression [$F_{1,15} = 0.64$, $p = 0.029$, $\eta^2 p = 0.28$, op = 0.62], anger [$F_{1,15} = 0.11$, $p = 0.066$, $\eta^2 p = 0.21$, op = 0.46], confusion [$F_{1,15} = 0.84$, $p = 0.031$, $\eta^2 p = 0.27$, op = 0.60], and total [$F_{1,15} = 0.41$, $p = 0.006$, $\eta^2 p = 0.41$, op = 0.85].

The post hoc test showed that both groups presented significant decreases in tension, confusion, and total BRUMS from the first to tenth days (p = 0.020, 0.020, 0.013), in both the before and after assessments, but with no significance from the first to tenth days. Regarding comparison within the before and after assessments, on the first day, the participants decreased tension ($p = 0.019$), depression ($p = 0.048$), confusion (marginally decreased: $p = 0.062$), and total ($p = 0.019$). For tension, there was also a significant decrease on the tenth day ($p = 0.041$) (Figure 2).

3.2. HR. There was a main effect for Moments [$F_{1,8} = 6384.3$, $p = 0.003$, $\eta^2 p = 0.68$, op = 0.95]. The post hoc test showed that HR significantly increased between the before and after intervention assessments on all days, except for the eight day. Regarding days of intervention, although the ANOVA did not find a significant main effect, the post hoc test showed significant increases in the HR from the first to fourth days ($p = 0.033$) and from the first to ninth days ($p = 0.005$) (Figure 3). The analysis between groups showed a significant difference between the BC and CG groups for before ($p = 0.004$) and after ($p = 0.040$) moments on the first day.

3.3. RPE. There were main effects for Moments [$F_{3,216} = 775.7$, $p < 0.001$, $\eta^2 p = 0.91$, op = 1.0] and marginally significant for days [$F_{9,216} = 112.3$, $p = 0.074$, $\eta^2 p = 0.22$, op = 0.63]. The post hoc test showed that both groups presented significantly increased RPE values within all Moments ($p < 0.001$), while within days, the difference was significant from the first to fourth days ($p = 0.006$), the first to five days ($p = 0.049$), and the first to ninth days ($p = 0.056$). The analysis between groups showed that there was no significant difference between the BC and CG ($p = 0.605$) only at the baseline moment (Mo0), while for all the other moments (Mo1, Mo2, and Mo3), the difference between groups was $p < 0.001$ (Figure 4).

Table 1: Demographic data.

Variables	Control group (CG) n = 28 Mean ± standard deviation	Breast cancer (BC) n = 30 Mean ± standard deviation	p value
Age	50.2 ± 9.2	50.7 ± 9.8	0.847
	n (%)	*n* (%)	*n* (%)
Schooling			
Incomplete high school	0 (0.0)	1 (3.3)	0.120
Complete high school	11 (39.3)	5 (16.7)	
Incomplete college	0 (0.0)	2 (6.7)	
Complete college	17 (60.7)	22 (73.3)	
Working			
Yes	20 (71.4)	18 (60.0)	0.185
Left job	0 (0.0)	12 (40.0)	*< 0.001*
Physical activity			
Yes	18 (78.4)	20 (66.6)	0.982
Associated diseases			
Systemic arterial hypertension	5 (17.9)	5 (16.7)	0.589
Diabetes mellitus	0 (0.0)	1 (3.3)	0.517
Breast cancer details		**n (%)**	
Affected side			
Left		14 (46.7)	
Right		14 (46.7)	
Bilateral		2 (6.7)	
Chemotherapy		27 (90.0)	
Radiotherapy		21 (70.0)	
Surgical approach			
Mastectomy without reconstruction		11 (36.7)	
Unilateral mastectomy with reconstruction		7 (23.3)	
Bilateral mastectomy with reconstruction		1 (3.3)	
Quadrantectomy		8 (26.7)	
Lumpectomy		1 (3.3)	
Adenostectomy		2 (6.7)	
Axillary emptying		19 (63.3)	
Physiotherapy		26 (86.7)	

Note: The italic significance is $p = 0.001$.

Figure 5 presents the relations of HR with the phases of the game, as well as RPE and the phases of the game. It is possible to see that the phase and difficulty of the game increased, while the RPE and HR remained almost unchanged.

4. Discussion

In the current study, we investigated the influence of a nonimmersive VR telerehabilitation intervention in women diagnosed with breast cancer, to analyze whether playing the virtual task would enhance mood, HR, and RPE. We found that it was possible for women diagnosed with breast cancer to participate at any time during treatment and that the intervention was safe and viable for participants, considering that there were no adverse effects during the protocol, such as dizziness, falls, nausea, or pain.

Our hypotheses were partially supported: The individuals with breast cancer presented increased perception of exertion and HR during practice, but with a lower increase compared to the control group, as expected. Moreover, we identified a positive affective influence in just a few mood states according to the BRUMS. We will discuss the results in detail considering (1) the perception of exertion and HR and (2) the Mood scale.

4.1. Perception of Exertion and Heart Rate. An important finding was that the VR intervention led to an increased RPE and HR, suggesting that the game used promotes an increase in physical activity. This result supports the review by Mitchell et al. [17], emphasizing the necessity for further studies in order to establish the feasibility of the game as a therapeutic modality for rehabilitation. This result is in agreement with the meta-analysis of Hao et al., which showed positive effects on physical, cognitive, and psychological aspects of patients with cancer using VR rehabilitation tasks. The authors emphasized that VR can be incorporated into a comprehensive cancer rehabilitation program to alleviate impairments and functional limitations [18]. When comparing the two groups (i.e., the control group participated only on the first day), we observed that the control group exhibited a lower HR and perceived exertion increases than the CG. We can only hypothesize that

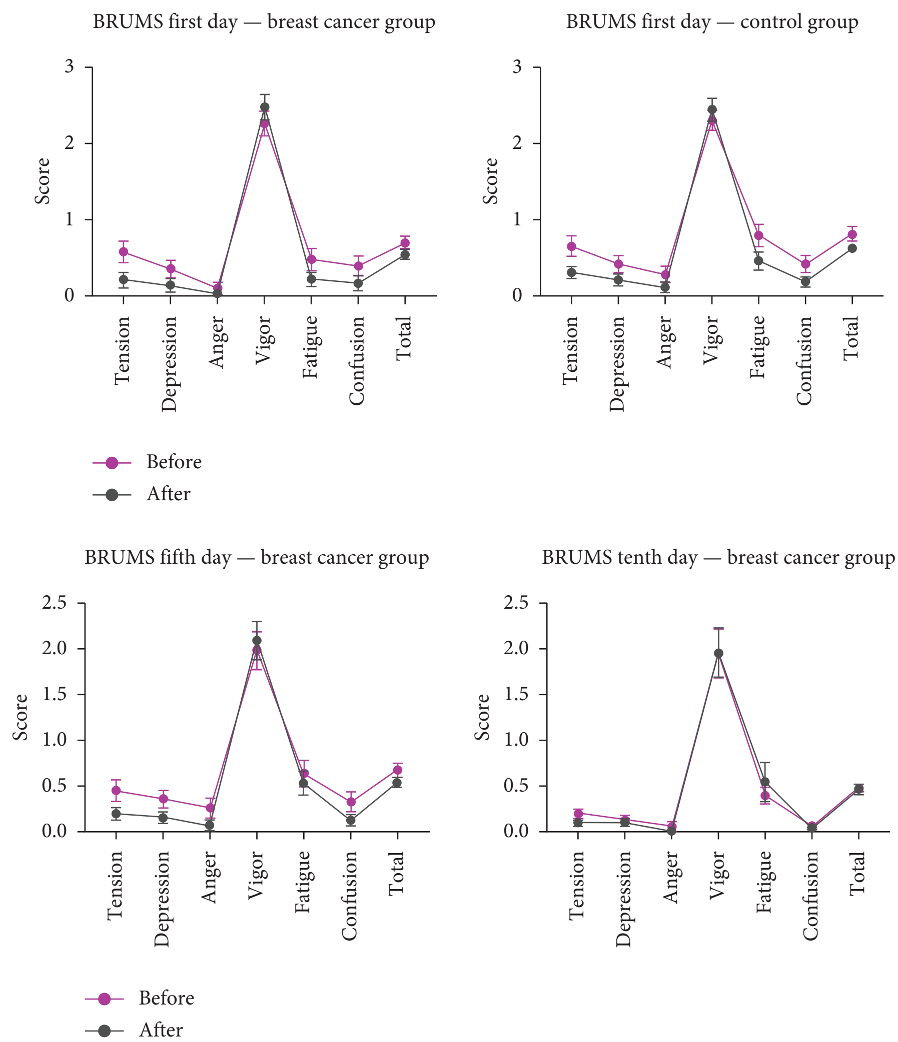

Figure 2: BRUMS items on the first, fifth, and tenth days, before and after the interventions.

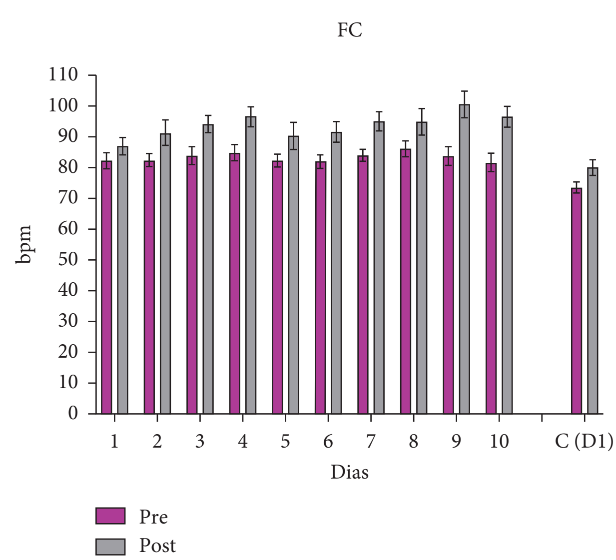

Figure 3: Heart rate scale items from first to tenth days, before and after the intervention. Legend: C, control group; D1, first day; bpm, beats per minute; HR, heart rate.

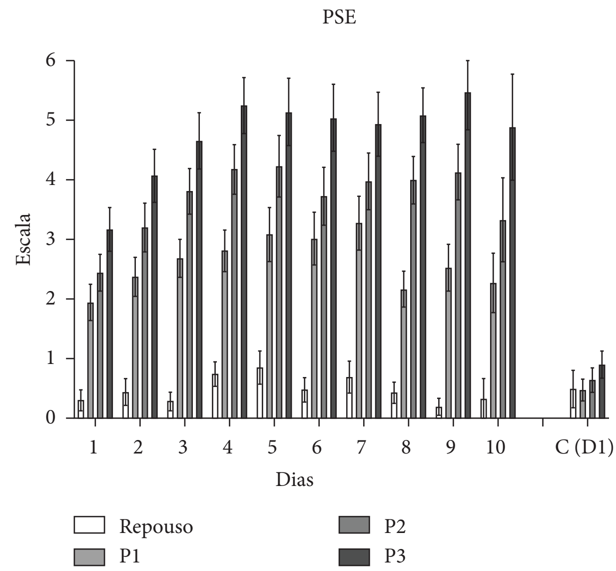

Figure 4: RPE from first to tenth days, at the four assessments during the intervention. Legend: C, control group; D1, first day; RPE, rating of perceived exertion; Mo0, moment 0; Mo1, moment 1; Mo2, moment 2; Mo3, moment 3.

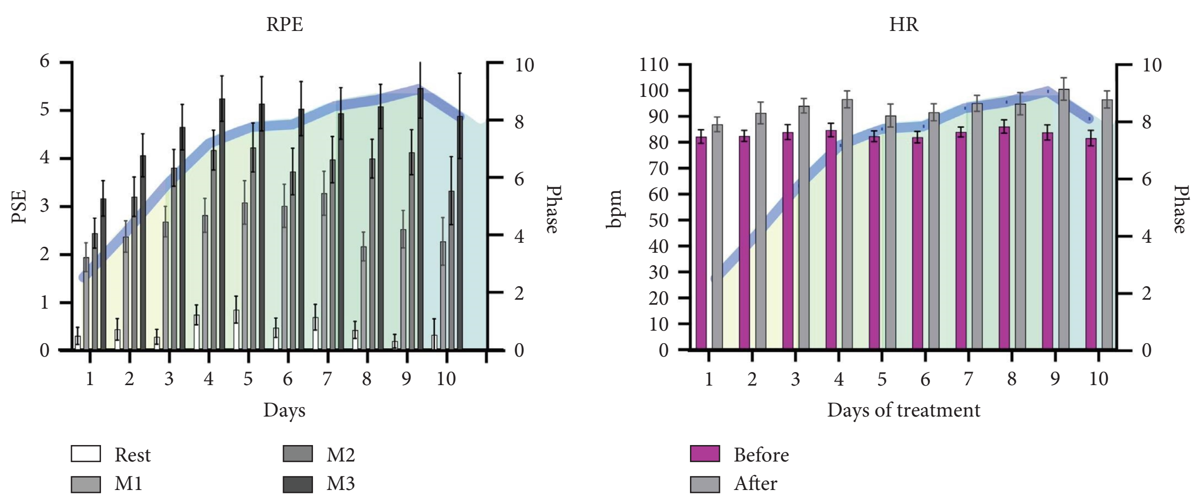

Figure 5: Relation of the HR and RPE with the phases of the game, from first to tenth days. RPE, rating of perceived exertion; HR, heart rate; M1, moment 1; M2, moment 2; M3, moment 3; phase, game phases; bpm, beats per minute.

the difficulty level proposed for the control group was too low to significantly enhance the physical activity of this group.

Another important finding was the possibility of using the game to increase the HR and perceived exertion during practice (i.e., during the 10 days of practice, we observed increases in the HR and RPE). This is an important result, showing that by practicing the game participants improved their metabolic capacity, as the phase and difficulty of the game increased, while the RPE and HR remained almost unchanged. Furthermore, during the game, the HR reached a value close to 100 bpm and an RPE of 5, which is considered an important value for promoting exercise and improvements in metabolic and cardiovascular health. This mean HR demonstrates that VR promoted low-intensity physical activity, as they reached 60% of their HR max and 20% of their reserve HR, considering their average age of 50 years.

A recent meta-analysis backs our findings, providing evidence that higher postdiagnostic levels of physical activity are beneficial and can lower mortality rates in women diagnosed with breast cancer. These results support the development of lifestyle recommendations for breast cancer survivors to be physically active [19]. During exercise, HR variability (HRV) gradually decreases until it stabilizes. The autonomic modulation of HRV in patients with chronic degenerative and metabolic diseases is frequently altered and is considered a predictor of morbidity and mortality. Exercise can be a positive means for cardiovascular nursing, as it improves the function of the cardiovascular system, in addition to reducing SBP levels, in patients with breast cancer. The increase in HR caused by physical exercise has been associated with a decrease in the mortality rate. Cardiovascular diseases are the leading cause of death in breast cancer survivors [20].

4.2. Mood Scale. The results demonstrated that VR reduced tension, confusion, and depression in both groups. Our findings are exciting and provide support on both how to implement a gaming intervention and the need for a remote trial to investigate the effectiveness of games in motivating low-intensity physical activity in people with breast cancer. Studies have also shown that VR is capable of improving the emotional aspects and mood of participants [21]. Ioannou et al. [22] realized a randomized crossover trial with 50 cancer patients undergoing chemotherapy treatment and showed that VR is able to cause positive mood changes in chemotherapy patients. Patients experienced a better mood state effect, for all mood subscales, after a VR intervention compared to guided imagery (GI). A systematic review evaluated the effects of VR-based interventions on anxiety, pain, depression, fear, anguish, and quality of life in cancer patients, including 12 studies involving 425 participants from the intervention group and 400 participants from the control group. The results showed a significant difference between the VR and control groups for anxiety; that is, VR interventions were effective in improving physical and psychological symptoms in cancer patients [23].

5. Conclusion

The participants with breast cancer showed increases in their RPE and HR during the interventions, even though the difficulty of the game increased, providing evidence of improvements in their metabolic capacity. In addition to the metabolic improvement, telerehabilitation was positive for the mood of the participants.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon request (talita.dias@unifesp.br).

Ethics Statement

The study was approved by the Research Ethics Committee of the Federal University of São Paulo (UNIFESP) under No. CAAE: 33293720.9.0000.5505.

Conflicts of Interest

The authors declare no conflicts of interest.

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