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Original Article

Evaluation of the exercise intensity generated by active video gaming in patients with cystic fibrosis and healthy individuals

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ABSTRACT

Background: Adherence of patients with cystic fibrosis (CF) to exercise is challenging. Here we compared the physiological responses during the use of interactive video games (VG) with the cardiopulmonary exercise test (CPET) in healthy and CF subjects.

Methods: Cross-sectional study including CF and healthy (CON) subjects older than 6 years. Individuals were evaluated in two visits. At visit one, anthropometric measures, spirometry and CPET were performed. In the second visit, a physical activity questionnaire was applied and gas analyses performed during the use (10 min) of both Nintendo Wii (Wii Fit Plus: (1) Obstacle Course, (2) Rhythm Boxing and (3) Free Run) and Xbox One (Just Dance 2015: (1) Love Me Again, (2) Summer and (3) Happy).

Results: Twenty-five CON and 30 CF patients were included. The mean FEV_1 (%) was significantly lower in the CF group compared to CON. There were no differences between groups at peak exercise (CPET) for heart rate (HR), oxygen consumption (VO_2) and minute ventilation (V_E). In the CON group, games 2 and 3 (Xbox) and game 3 (Nintendo) increased HR to values similar to the anaerobic threshold (AT), while for the CF group this occurred for games 2 (Xbox) and 3 (Nintendo). As for VO_2 and V_E, both groups obtained similar responses as compared to AT values in games 2 (Xbox) and 3 (Nintendo).

Conclusion: The use of VG generated a cardiorespiratory response similar to AT levels found during CPET, indicating that it may be an alternative for exercise training of CF individuals.

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1. Introduction

Cystic fibrosis (CF) is a recessive genetic disorder caused by mutations in the cystic fibrosis transmembrane conductance regulator (CFTR) gene. It affects multiple parts of the body, including the respiratory, gastrointestinal, and reproductive systems [1]. These changes lead to recurrent infections and inflammatory processes that impair nutritional status, pulmonary function, and exercise capacity [1].

CF treatment requires a multidisciplinary team and should be tailored to the needs of each patient [2]. Physical exercise is an important step in recommendations of clinical management, as it contributes to reducing dyspnea, increasing cardiorespiratory fitness, and improving mucociliary clearance and emotional well-being [2]. Patients with lower peak oxygen uptake (VO_2peak) have a higher mortality rate [3]. Also, moderate- to vigorous-intensity physical activity for at least 60 min a day may help maintain a healthy cardiorespiratory and metabolic system, as high levels of sedentary behavior are associated with health problems [4].

However, most young people with CF do not follow recommendations of daily physical activity [5], and engagement tends to decrease as age advances [6]. In addition, complex treatment adherence in patients with CF has been shown to be poor [6], and exercise adherence has been considered a challenge. Nevertheless, studies have supported the hypothesis that exercise programs using active video games may increase treatment adherence [7], as those games seem to provide more satisfaction than conventional exercise programs [8,9].

A limitation for using video games as part of exercise training in clinical practice is whether such games will be able to generate the required cardiorespiratory demand to be prescribed as an

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exercise modality. Classically, aerobic exercise prescription is based on percent of maximal heart rate (HRmax) or VO_2peak as measured in the cardiopulmonary exercise testing (CPET) [10]. A systematic review has shown that active video gaming generates a heart rate (HR) response similar in intensity to that required for exercise training in patients with CF [11]. However, to date, no study has examined cardiorespiratory demand through respiratory gas analysis during active video gaming compared to CPET, which is considered the gold standard for exercise capacity assessment [12].

Thus, this study aimed to evaluate whether the use of active video games by patients with CF and healthy individuals produces the required cardiorespiratory demand for aerobic physical training, having CPET performance as reference. The study also compared responses generated by different Nintendo Wii and Xbox One video games, as well as level of acceptability of those games.

2. Methods

This cross-sectional study included a convenience sample of patients aged above 6 years who were being followed at a Cystic Fibrosis Center and healthy individuals, matched by age and sex. The participants were divided into 2 groups, namely cystic fibrosis (CF) group and control (CON) group. The following inclusion criteria were used for each group: CF group - patients with confirmed clinical diagnosis of CF (sweat test or genetic test) and presenting with stable clinical state at the day of assessment; CON group - healthy individuals, based on a respiratory health questionnaire review and lung function analysis. Individuals who failed to perform any of the tests proposed in the study (spirometry, CPET, or video gaming) were excluded. The study protocol was registered under number NCT03229213 (www.clinicaltrials.gov). All procedures followed national guidelines for research on human subjects and were approved by the University Research Ethics Committee (protocol number 68731617.9.0000.5336).

Sample size calculation was based on the study of Del Corral et al. [13]. Considering the VO_2 (mL.m^{-1}) standard deviations for both the exercise test (282) and videogame (113), power of 95%, significance level of 5%, correlation between variables of 0.7, and difference between means of 150 mL.m^{-1}, the estimated sample size was 28 individuals in each group.

2.1. Study design

Patients with CF were invited to participate according to eligibility criteria. After they signed informed consent and assent forms, anthropometric measures (weight and height) were collected and CPET was performed to assess cardiorespiratory responses during exercise. Clinical and genetic data were collected from medical records.

In a subsequent scheduled visit, patients completed a questionnaire to assess physical activity level and played video games in two consoles (Nintendo Wii and Xbox One), with 10-minute intervals, to assess physiological variables. The sequence of games was randomly chosen. During the test, patients used an accelerometer to measure physical activity level.

Concomitantly, healthy individuals (CON group) were invited to participate and performed the same tests as the CF group. In the first visit, they were submitted to a respiratory health questionnaire, anthropometric measurement, spirometry, and CPET, while in the second visit, they completed a questionnaire to assess physical activity level and played video games [14].

2.2. Procedures

2.2.1. Anthropometry

Weight and height measurements were performed in triplicate. The weight was measured with subjects in standing using a digital scale (G-tech, Glass 1 FW, Rio de Janeiro, Brazil) with 100 g accuracy. The height was measured using a stadiometer (AlturaExata, TBW, São Paulo, Brazil) with participants barefoot. The body mass index (BMI) was calculated and expressed in kg/m^2. The WHO Anthroplus program was used to calculate the z-scores [14].

2.2.2. Clinical and genetic data

These data were collected from medical records, including presence of pancreatic insufficiency, chronic colonization with *Pseudomonas aeruginosa*, and type of mutation. Chronic colonization with *Pseudomonas aeruginosa* was based on results of previous three samples of oropharyngeal swab or sputum collections that had positive culture in a period of six to nine months and were treated with antibiotics in the same period [15].

2.2.3. Respiratory health questionnaire

Healthy individuals completed a questionnaire for children and adolescents consisting of 18 questions about respiratory health. There were questions about parental history of tobacco use during pregnancy, family history of asthma, symptoms of asthma or bronchitis, as well as allergic rhinitis [16].

2.2.4. Physical activity questionnaire

Physical activity levels were assessed using a short version of the International Physical Activity Questionnaire (IPAQ). Participants aged up to 15 years completed IPAQ-C and were classified as active (score $\geq$ 3) or sedentary (score $<$ 3). This score represents an average of points, which takes into account physical activity practiced at different times, including children's free time, school break, physical education class, as well as the type of activity performed on each day of the last week. Participants aged above 15 years completed IPAQ-A and were classified as active if they summed 150 min/week of moderate-intensity physical activity, divided into at least 3 times/week, or vigorous-intensity physical activity for at least 3 sessions of 20 min/week [17].

2.2.5. Lung function

Spirometry was performed using a KOKO spirometer device (Louisville, CO, USA). The test followed technical standards and acceptability and reproducibility criteria of the American Thoracic Society–European Respiratory Society (ATS/ERS) [18]. The variables assessed in the test were forced vital capacity (FVC), forced expiratory volume in 1 s (FEV_1), Tiffeneau-Pinelli index (FEV_1/FVC), and forced expiratory flow between 25 and 75% of FVC ($FEF_{25-75\%}$). The data were described as liters and percent of the predicted value as calculated using an international equation [19].

2.2.6. Cardiopulmonary exercise testing

The test followed the recommendations of the American Thoracic Society and the American College of Chest Physicians [20], as well as recent CF guidelines [12]. It was performed using a computer system (Aerograph, AeroSport®, USA) coupled to a gas analyzer (VO_{2000}, MedGraphics®, USA) and using a treadmill (KT-10400, Inbramed®, Brazil). The collected variables included VO_2peak, maximal minute ventilation (V_E), respiratory exchange ratio (RER), peripheral oxygen saturation (SpO_2), subjective levels of dyspnea and lower limb muscle fatigue (modified Borg scale), oxygen pulse (VO_2/HR), ventilatory equivalent for oxygen consumption (V_E/VO_2) and for carbon dioxide production (V_E/VCO_2), and HRmax. HRmax was measured using a heart rate monitor (Polar®), and SpO_2 was monitored using a pulse oximeter (DX2405, Dixtal®, Brazil).

In the test, participants were first instructed to walk for 2 min to adapt to the treadmill, with a speed of 3 km/h and no incline. Then, the speed was increased by 0.5 km/h every minute with a constant 3% incline until the end of the test. All participants were encouraged to keep the pace until exhaustion or appearance of limiting signs and/or symptoms (dyspnea, leg pain, and/or dizziness). The anaerobic threshold was non-invasively identified using a combination of the V-slope method and ventilatory equivalents [21]. To reach a maximal test, at least three of the following criteria should be observed: exhaustion or inability to maintain the required speed, RER >1.0, HRmax >180 bpm, and a VO_2 plateau [12,20].

2.2.7. Active video gaming

The participants played Nintendo Wii and Xbox One video games for 10 min, in a random sequence, with a 10 min interval between games. While playing, they used a neoprene face mask connected to a gas collection system (VO_{2000}, MedGraphics®, USA) to assess the same variables as in the CPET. The participants played three games in each console: Nintendo Wii (Wii Fit Plus) - (1) Obstacle Course, (2) Rhythm Boxing, and (3) Free Run; and Xbox One (Just Dance 2015) - (1) Love Me Again - John Newman, (2) Summer - Calvin Harris, and (3) Happy - Pharrell Williams. Data analysis used means of the last 30 s of each game for both consoles.

2.2.8. Accelerometer

All participants used a triaxial accelerometer (wGT3X-BT®) while playing video games. The results were expressed as mean number of total steps/minute [22].

2.2.9. Perceived exertion

The OMNI scale, in cycle format, was used [23]. A team member explained the scale to children and adolescents. After finishing the last game, the participants answered the question "How tired did you feel while playing?" with a score ranging from 0 to 10.

2.2.10. Satisfaction level

Satisfaction level was measured using a 5-point Likert-type scale. At the end of the last game in each console, participants graded their satisfaction level from 1 (no satisfaction) to 5 (high satisfaction).

2.3. Statistical analysis

The normality of the data was evaluated by the Shapiro-Wilk test. Continuous data that presented normal distribution were expressed as mean and standard deviation, while asymmetric data were presented as median and interquartile range. Categorical variables were presented in absolute and relative frequency. Comparison of the sample characteristics between groups was performed using the Student's *t*-test for independent samples or the Man

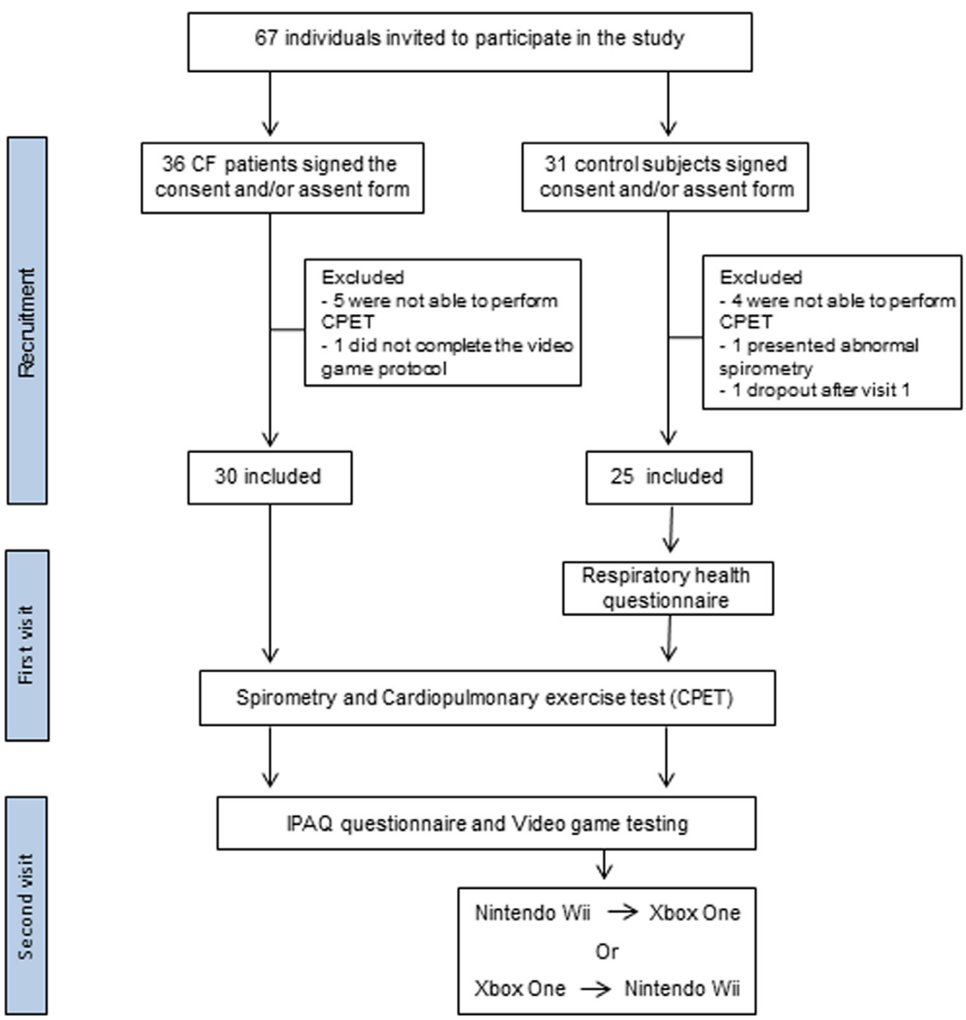

Fig. 1. Study flowchart.

Table 1
Characterization of the study sample.

Variables evaluated	Healthy ($n = 25$)	CF ($n = 30$)	p
Demographic			
Age, years	16.2 (5.0)	16.9 (5.1)	0.61
Male, n (%)	13 (52.0)	19 (63.3)	0.23
Anthropometry			
Weight (kg)	54 (13)	54 (17)	0.95
Height (cm)	161 (16)	158 (18)	0.59
BMI (absolute)	21.1 (3.3)	19.5 (3.0)	0.06
BMI (z score)	1.0 (1.7)	0.5 (1.0)	0.34
Clinical			
Pancreatic insufficiency, n (%)	–	25 (83.3)	–
Diabetes mellitus, n (%)	–	3 (10.0)	–
Chronic *P. aeruginosa*, n (%)	–	5 (16.7)	–
Age of diagnosis, years	–	5.1 (4.2)	–
Genotype – n (%)			
F508del Homozygous	–	3 (10.0)	–
F508del Heterozygous	–	17 (56.7)	–
Other mutations	–	10 (33.3)	–
Lung Function			
FEV_1 (L)	3.4 (1.1)	2.3 (0.97)	*<0.001*
FEV_1 (% predicted)	105 (13)	73 (24)	*<0.001*
FVC (L)	3.8 (1.3)	3.0 (1.07)	*0.009*
FVC (% predicted)	101 (11)	81 (20)	*<0.001*
FEV_1/FVC (absolute)	0.90 (0.07)	0.77 (0.12)	*<0.001*
$FEF_{25-75\%}$ (L/min)	4.1 (1.4)	2.1 (1.2)	*<0.001*
$FEF_{25-75\%}$ (% predicted)	108 (22)	61 (32)	*<0.001*
Physical activity level			
IPAQ-A, min*			
Sitting	810 (720–1080)	630 (540–1080)	0.26
Walking	90 (0–210)	105 (60–295)	0.51
Moderate/vigorous activity	70 (0–345)	135 (60–200)	0.33
IPAQ-C	2.5 (0.8)	2.5 (0.3)	0.99

CF: cystic fibrosis; BMI: body mass index; FEV_1: forced expiratory volume in one second; FVC: forced vital capacity; $FEF_{25-75\%}$: forced expiratory flow between 25 and 75% of vital capacity. Values expressed as mean (standard deviation) or n (%), except for IPAQ-A min*, expressed as median (interquartile range).

Whitney test. Associations were assessed by Pearson's chi-square test. Comparisons between CPET cardiorespiratory variables and the different games (Nintendo Wii and Xbox One) were performed using an one-way ANOVA test, followed by the Bonferroni post-hoc test. All analyzes and data processing were performed in the SPSS 18.0 program and the significance level adopted was 5% ($p < 0.05$).

3. Results

3.1. Study population and overall demographics

Of a total of 67 screened individuals, 12 were excluded as shown in the study flowchart (Fig. 1). The final sample consisted of 55 participants, including 25 controls (16.2 ± 5.0 years) and 30 patients with CF (16.9 ± 5.1 years). There were no significant differences in demographic and anthropometric variables between the groups (Table 1). As expected, patients with CF had lower lung function values than controls. The mean FEV_1 (%) in the CF group was 73.3 ± 24, suggesting a mild impairment. There were no significant differences in physical activity level (as measured in IPAQ-A and IPAQ-C) between the groups. In adolescents, the median time of moderate- to vigorous-intensity physical activity was 70 min per week in the CON group and 135 min per week in the CF group, suggesting a sample of physically inactive individuals. Children were also found to be poorly active in both groups, with a mean score of 2.5 points (Table 1).

3.2. Exercise capacity evaluation

Regarding CPET data (Table 2), the CF group had a slightly lower resting SpO_2 ($p < 0.001$), but no other significant differences were found at rest compared to the CON group. No signif-

Table 2
Results of the cardiopulmonary exercise test.

Variables evaluated	Healthy ($n = 25$)	CF ($n = 30$)	p
Resting			
HR (beats/min)	88 (12)	87 (16)	0.87
SpO_2 (%)	98 (1.4)	97 (1.6)	*<0.001*
RER	0.83 (0.05)	0.84 (0.05)	0.27
VO_2 (L.min^{-1})	0.37 (0.12)	0.38 (0.15)	0.70
VO_2 (mL.kg^{-1} min^{-1})	7.3 (2.7)	7.6 (2.7)	0.67
V_E (L.min^{-1})	9.4 (2.7)	9.3 (2.7)	0.81
Borg for dyspnea	0.2 (0.4)	0.1 (0.4)	0.58
Borg for leg fatigue	0.2 (0.5)	0.3 (0.9)	0.63
Anaerobic threshold			
HR (beats/min)	154 (24)	153 (22)	0.93
VO_2 (L.min^{-1})	1.50 (0.50)	1.30 (0.43)	0.98
VO_2 (mL.kg^{-1} min^{-1})	26.4 (8.2)	26.1 (7.5)	0.94
VO_2 (%máx)	73 (15)	73 (18)	0.63
V_E (L.min^{-1})	32.4 (10.4)	29.1 (9.1)	0.22
Peak exercise			
HR (beats/min)	186 (9)	180 (13)	0.54
SpO_2 (%)	97 (1.3)	94 (4.5)	*<0.001*
RER	1.11 (0.07)	1.10 (0.08)	0.37
VO_2 (L.min^{-1})	2.02 (0.5)	1.90 (0.6)	0.45
VO_2 (mL.kg^{-1}.min^{-1})	36.7 (8.5)	36.9 (6.4)	0.94
VO_2 (percentile)*	15 (2–25)	15 (10–50)	0.30
V_E (L.min^{-1})	54.2 (16.3)	50.0 (17.2)	0.35
V_E/VO_2 (L.min^{-1})	22.4 (2.9)	23.8 (3.7)	0.12
V_E/VCO_2 (L.min^{-1})	21.6 (2.4)	23.3 (3.4)	*0.04*
Borg for dyspnea	4.2 (2.4)	4.3 (2.9)	0.84
Borg for leg fatigue	4.6 (3.4)	5.5 (3.2)	0.27

CF: cystic fibrosis; HR: heart rate; RER: respiratory exchange ratio; V_E: minute ventilation; V_E/VO_2: ventilatory equivalent ratio for oxygen uptake; V_E/VCO_2: ventilatory equivalent ratio for carbon dioxide production; VO_2: maximal oxygen uptake. Values expressed as mean (standard deviation), except for VO_2 (percentile)*, expressed as median and interquartile range.

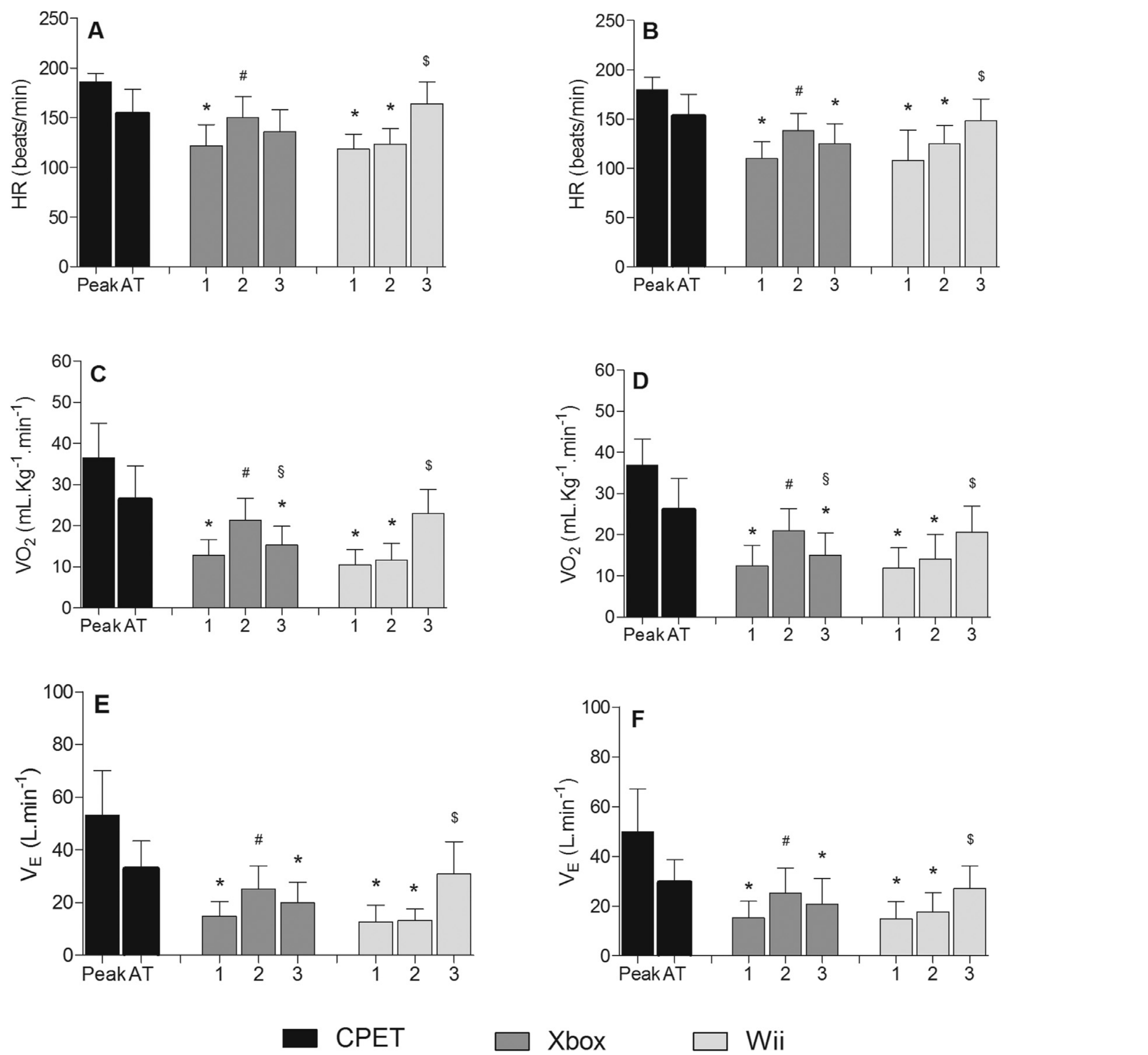

Fig. 2. Comparison of the physiological responses using interactive video games with the anaerobic threshold (AT) and peak exercise values from the cardiopulmonary exercise test (CPET). Controls (A, C and E) presented in the left and cystic fibrosis patients (B, D and F) in the right. Heart rate (HR) in A and B; Oxygen consumption (VO_2) in C and D; and Ventilation (V_E) in E and F. *indicates significant difference compared to AT; #indicates significant difference of game 2 compared to game 1 (Xbox); §indicates significant difference of game 3 compared to game 2 (Xbox); $indicates significant difference of game 3 compared to games 1 and 2 (Nintendo Wii).

icant differences in anaerobic threshold (AT) data were found between the groups. At peak exercise, the CF group had decreased SpO_2 ($p < 0.001$) and increased V_E/VCO_2 ($p = 0{,}04$), showing the need of higher V_E to eliminate the same amount of CO_2 compared to the CON group. No significant differences were found for VO_2 peak between groups.

3.3. Video game physiological responses

To assess video game-related physiological responses, HR, VO_2, and V_E values in the games were compared to AT values obtained in the CPET (Fig. 2). Xbox One game 2 (Summer) and Nintendo Wii game 3 (Free Run) produced responses that were similar (without significant differences) to AT values in both groups, suggesting that these games generate the required physiological demand for physical training. When the three Xbox One games were compared, game 1 (Love Me Again) produced lowest physiological responses ($p < 0.05$), while game 3 (Happy) generated a HR response similar to AT value in controls, but not in patients with CF. Also, Nintendo Wii games 1 (Obstacle Course) and 2 (Rhythm Boxing) had differences in all variables ($p < 0.05$) in both groups when compared to AT values. As expected, there were significant differences in all games when peak CPET values were compared (Fig. 2).

When the physiological demand (in metabolic equivalents - METs) produced by video games was analyzed, Xbox One game 2 (Summer) and Nintendo Wii game 3 (Free Run) reached a moderate-intensity range (3–6 METs) in both groups. Conversely, Xbox One game 3 (Happy) produced that effect only in controls (Fig. 3). The assessment of subjective sensation of dyspnea (Borg for dyspnea), lower limb muscle fatigue (Borg for leg fatigue), exertion (OMNI scale), and satisfaction level is shown in Table 3. There were no significant differences in those variables between the groups. However, it is worth noting that satisfaction level with video games was high. Finally, there were no significant differences between consoles in total number of steps as measured by the accelerometer in both groups (Supplementary Figure 1).

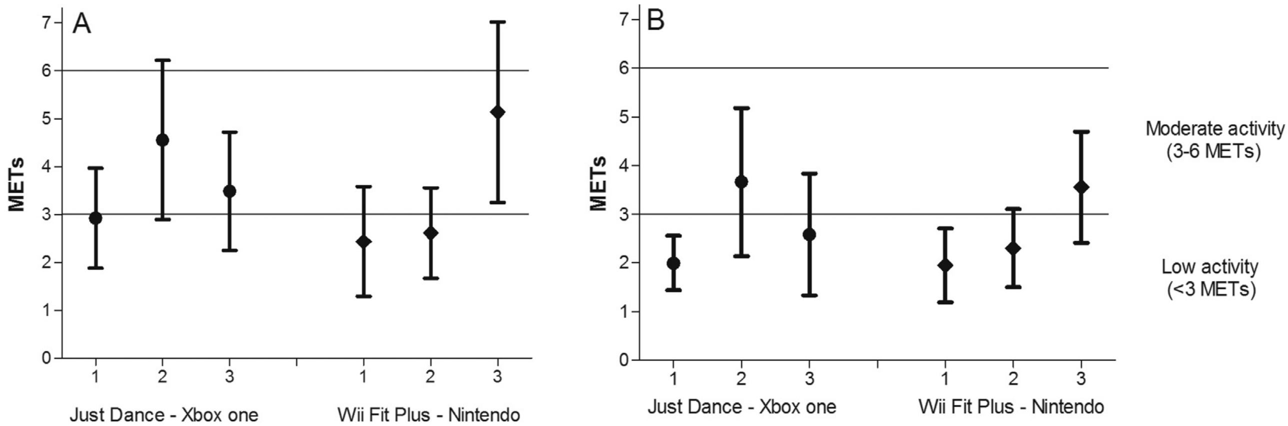

Fig. 3. Representation of the metabolic demand (METs) reached by the participants of the control group (A) and cystic fibrosis (B) for each of the games tested. For better visualization, lines marking the level of moderate activity (3 to 6 METs) were included.

Table 3
Evaluation of the subjective sensation of dyspnea, fatigue in lower limbs, effort and satisfaction.

Variables evaluated	Xbox One			Nintendo Wii		
	Healthy ($n = 25$)	CF ($n = 30$)	p	Healthy ($n = 25$)	CF ($n = 30$)	p
Borg for dyspnea (rest)	0.0 (0.1)	0.2 (0.4)	0.17	0.0 (0.2)	0.5 (1.2)	0.87
Borg for dyspnea (end of game)	2.6 (3.1)	2.7 (2.4)	0.83	1.8 (2.1)	3.5 (2.8)	0.70
Borg for leg fatigue (rest)	0.1 (0.3)	0.3 (0.8)	0.40	0.2 (0.6)	1.0 (2.5)	0.10
Borg for leg fatigue (end of game)	2.8 (3.0)	3.0 (2.4)	0.86	2.3 (2.9)	3.4 (3.2)	0.19
OMNI scale	4.2 (1.7)	4.6 (1.9)	0.30	4.6 (1.8)	4.9 (2.0)	0.47
Satisfaction	4.6 (1.1)	4.3 (0.9)	0.40	4.7 (0.7)	4.4 (0.8)	0.11

CF: cystic fibrosis. Values are expressed as mean (standard deviation). p: indicates the level of significance when comparing the control and CF groups.

4. Discussion

The results of the present study confirm the hypothesis that active video gaming may be a physical training alternative both for patients with CF and for healthy individuals. Some games were able to increase cardiorespiratory responses to the level of intensity recommended for aerobic training. These findings are consistent with data from a recent systematic review on the topic, in which active video gaming was shown to generate a HR response similar to that required for training [11].

Our findings demonstrate that both Xbox One and Nintendo Wii raised HR, V_E, and VO_2 to levels close to those obtained in the CPET (AT values). To the best of our knowledge, this is the first study that evaluated physiological responses using respiratory gas analysis during active video game therapy and that compared them to CPET results in patients with CF and healthy individuals. A recent study found that use of Nintendo Wii caused increased metabolic stress (HR and VO_2) compared to 6-minute walk test [13]. However, it should be noted that the test used for comparison is submaximal. In addition, a controlled study revealed that active video gaming may increase energy expenditure (METs) in moderate-intensity physical activity, depending on the game selected [24]. Overall, our results are consistent with physiological response levels found in other studies evaluating active video gaming [11]. However, it is worth noting that game selection seems to be important to obtain the expected physiological effects.

Regarding types of games, our results show that racing and dance games have potential to reach moderate intensity for exercise training. According to O'Donovan et al., Wii Fit "Free Jogging", but not Wii Sport "Boxing", is a game that may be recommended as moderate-intensity aerobic exercise for patients with CF and healthy individuals [24]. Similarly, Clevenger et al. demonstrated that "Dance Central" and "Zumba/Your Shape" generate a moderate metabolic expenditure (in METs) in healthy individuals [25]. In the present study, "Just Dance 2015″ had a similar result with the song "Summer". The other songs did not have the same effect, but this may be related to the type of movement used during the game. In addition, Wii Fit "Rythym Boxing" produced low-intensity training, confirming the findings of the study of Sanders et al., who reported a 53% HR response in "Wii Boxing" and a perceived effort similar to treadmill walking. Conversely, Kinect "Boxing" generated a 65% HR response and greater perceived effort [26]. Also, our data showed that Wii Fit "Obstacle Course" produced low-intensity training (2 to 3 METs); however, only phases 1 and 2, whose difficulty level is lower, were included because of time of data collection. Furthermore, players are not constantly moving in Wii Fit "Obstacle Course" and Wii Fit "Rythym Boxing", which may hinder an increase in HR. It is also important to note that the use of "non-active" video games have been previously associated with childhood obesity and low physical activity levels [27], which reinforces the need of a specific recommendation for the use of active video games. Overall, the results confirm that game selection has a direct influence on physiological demand generated by active video game therapy.

The present study reported very similar responses in active video gaming between patients with CF and healthy individuals. Evidence from the literature [24] supports these findings. Also, no differences were found between the groups in exercise capacity as measured by CPET. Several factors may be associated with this effect, including (i) the extensive training recommendations for patients with CF, as an increase in $\dot{V}O_2$peak is associated with survival [3]; (ii) the mild compromise of lung function in the majority of the CF sample included in the present study, as the association between $\dot{V}O_2$peak and lung function has been already demonstrated [28]; and (iii) physical inactivity is a growing problem, as there is a tendency among children and adolescents to engage less in vigorous activities [29]. In addition, there is evidence that healthy individuals may have worst aerobic conditioning then patients with CF [30], although patients with CF have lower ventilatory reserve at peak exercise [31]. Regarding levels of daily physical activity, the questionnaires demonstrated that both groups were below recommendations, confirming the current sedentary trend in children and adolescents [6,7].

Studies have shown that exercise adherence is poor in patients with CF [32]. Thus, active video gaming could contribute to greater engagement in activities of enough intensity for physical training. However, increasing physical activity level needs a behavior change that is extremely difficult to obtain and maintain on the long range. A study of the impact of "Pokémon GO" on physical activity in young adults showed an initial increase of 955 daily steps after the game was installed, followed by a gradual decrease in the subsequent weeks and returning to initial levels after six weeks [33]. Nonetheless, the present results revealed high satisfaction levels in playing both Xbox One and Nintendo Wii. This finding is consistent with data showing that patients with CF prefer active games to conventional exercise [24]. Additionally, Salonini et al. reported that individuals express greater satisfaction when exercising with Xbox Kinect compared to cycle ergometer [8]. Adherence to a home-based active video game program was 95% in a six-week intervention [34]. Thus, active video gaming may be an important resource in an attempt to improve exercise adherence rates.

This study has some limitations, including time of collection (10 min) for each console. Performance in some games may have been influenced by the reduced time; as a consequence, the required physiological responses to obtain physical training effects were not reached. Conversely, a longer time for each game could have created a process of fatigue and influenced the results significantly. A strength of this study was real-time respiratory gas measurement during use of active video games and comparison to the gold standard for exercise capacity assessment (CPET).

5. Conclusion

Active video gaming in patients with CF and in healthy individuals generated the required cardiorespiratory demand for moderate-intensity aerobic physical training. However, these effects depended on game selection, with games Wii Fit "Free Run" (Nintendo Wii) and "Just Dance 2015″ (Xbox One, song Summer) being the ones that produced greater responses. Also, because the reported satisfaction level with active video gaming was high, this tool may be used as an exercise alternative to improve treatment adherence rates.

Author contributions

NEC: Project development, data collection, statistical analysis, writing of the manuscript. JPHF: Project development and revision of the manuscript. NAB: Data collection and revision of the manuscript. DS: Data collection and revision of the manuscript. MFG: Data collection and revision of the manuscript. ISA: Data collection and revision of the manuscript. MVFD: Project development, statistical analysis and revision of the manuscript.

Declaration of Competing Interest

The authors have no conflict of interests to disclose.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.jcf.2020.01.001.

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