

# Active Video Games as a Training Tool for Individuals With Chronic Respiratory Diseases

## A SYSTEMATIC REVIEW

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**Purpose:** Exercise is an effective treatment for reducing symptom severity and improving quality of life for patients with chronic respiratory diseases. Active video games offer a new and enjoyable way to exercise and have gained popularity in a rehabilitation setting. However, it is unclear whether they achieve comparable physiological and clinical effects as traditional exercise training.

**Methods:** A systematic literature search was performed to identify studies that included an active video game component as a form of exercise training and a comparator group in chronic respiratory disease. Two assessors independently reviewed study quality using the Cochrane risk of bias tool and extracted data for exercise capacity, quality of life, and preference of exercise model.

**Results:** Six studies were included in this review. Because of the heterogeneity of the populations, study designs, length of intervention, and outcome measures, meta-analysis could not be performed. Active video game training resulted in comparable training maximal heart rate and dyspnea levels to those achieved when exercising using a treadmill or cycle ( $n = 5$ ). There was insufficient evidence ( $n = 3$ ) to determine whether active video game training improved exercise capacity as measured by 6-min walk test or treadmill endurance walking.

**Conclusions:** Although the quality of evidence was low, in a small number of studies active video games induced peak heart rates and dyspnea levels comparable with traditional exercise training. Larger and longer-term randomized controlled trials are needed to establish the impact of video game training for individuals with chronic respiratory diseases.

**Key Words:** active video games • exercise training • exergames • respiratory disease

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Chronic respiratory diseases are characterized by symptoms of breathlessness, fatigue, and poor health-related quality of life (HRQOL).<sup>1-3</sup> Exercise training, often as part of pulmonary rehabilitation (PR), is an effective treatment to reduce the severity of symptoms and improve exercise capacity and health status.<sup>4-10</sup> Active video games, also referred to as “exergames,” are a novel approach to exercise training and have gained popularity in several areas of rehabilitation.<sup>11</sup> The most popular gaming systems are Nintendo Wii and Xbox 360 Kinect.<sup>12</sup> These systems use motion detection technology to mimic the movements of the players, which are reflected on-screen. There is a wide range of games that vary in the exercise intensity provided. Games such as Wii Fit are specifically intended to improve fitness levels and consist of strength training, aerobics (jogging/boxing), and balance games (yoga, skiing, snowboarding).<sup>13</sup> Other games such as Wii Sports and Kinect Sports promote physical activity through enjoyment while playing virtual sports either alone or with an opponent.

Active video games are well tolerated and enjoyed by patients with chronic respiratory diseases.<sup>14-19</sup> The game component may serve to increase motivation and adherence to exercise,<sup>18,20</sup> which is an important challenge for this population.<sup>21</sup> Therefore, they may offer an additional way of achieving exercise training as part of a supervised PR program, or at home.

While active video games provide a unique and enjoyable way to exercise, it is important to establish whether the physiological and clinical effects are equivalent to traditional exercise training. The primary aim of this systematic review was to determine the effects of active video game training on exercise capacity when compared with traditional exercise training in individuals with chronic respiratory diseases. The secondary aims were to determine the effects on symptom severity, energy expenditure, HRQOL and preference for exercise modality. This review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines<sup>22</sup> with the protocol registered on PROSPERO (CRD42016038724).

## METHODS

### DATABASES

Five electronic databases (MEDLINE, Excerpta Medica dataBASE [EMBASE], Cumulative Index to Nursing and Allied Health Literature [CINAHL], PubMed, and Physiotherapy Evidence Database [PEDro]) were searched in June of 2016. The searches consisted of combinations of terminology related to video games and chronic respiratory diseases and were adapted for each database. A detailed search strategy is included as Supplemental Digital Content 1, available at: <http://links.lww.com/JCRP/A67>. References of

identified articles and previous reviews were hand-searched for additional data sources. Both conference abstracts and peer-reviewed research articles were included. The search was updated on February 17, 2017.

### INCLUSION AND EXCLUSION CRITERIA

One researcher (S.J.B.) performed the initial search. Abstracts were independently reviewed for inclusion by 2 researchers (S.J.B. and A.L.L.). Inclusion criteria consisted of (1) clinical trials with an active video game (exergame) or virtual exercise training intervention; (2) participants with chronic respiratory diseases (asthma, bronchiectasis, chronic obstructive pulmonary disease [COPD], cystic fibrosis [CF], interstitial lung disease [ILD], lung cancer); (3) a comparator group performing traditional exercise modalities; and (4) information for at least 1 quantitative outcome related to exercise capacity. Conference abstracts were included and any duplicate articles were removed following the preliminary search.

Studies were excluded for the following reasons: (1) no comparison group; (2) qualitative studies; and (3) written in a language other than English.

### QUALITY ASSESSMENT

Two members of the research team (S.J.B. and A.L.L.) independently assessed the studies using the risk of bias tool from Cochrane,<sup>23</sup> with studies rated as unclear, low risk, or high risk. Any discrepancies were resolved by the researchers.

### DATA EXTRACTION AND ANALYSIS

Field walking test results, treadmill time and duration, ergometry, and maximal heart rate (HR) were included to reflect exercise capacity. Secondary outcomes included measures of dyspnea and perceived exertion to reflect breathlessness and fatigue, oxygen saturation (SpO<sub>2</sub>) indicating gas exchange, energy expenditure, measures of health status and HRQOL, and activity enjoyment.

Data extraction was performed by 1 member of the research team (S.J.B.) and verified by a second team member (A.L.L.). The type of data extracted included the disease population, type of intervention, frequency and duration

of the intervention sessions, comparator method, outcome measures, and key findings. Because of population variation, study design, and outcome measures, meta-analysis was not possible. Study findings were reported in a narrative format.

## RESULTS

### SEARCH RESULTS

As outlined in the Figure, the literature search identified 976 records. After duplicates were removed, 552 abstracts were screened for eligibility and 36 full-text articles and conference abstracts were included for full-text review. An additional 133 records were identified in the updated search following duplicate removal. Abstracts identified in the updated search were screened for eligibility and did not meet the inclusion criteria. Five research articles<sup>24-28</sup> and 1 conference abstract<sup>29</sup> met the inclusion criteria for individuals with asthma,<sup>24</sup> CF,<sup>25,28</sup> COPD,<sup>26,27,29</sup> ILD,<sup>27</sup> bronchiectasis,<sup>27</sup> or restrictive chest disease.<sup>27</sup> A summary of the included studies is provided in Table 1. Three randomized controlled trials<sup>24,27,29</sup> and 3 crossover studies<sup>25,26,28</sup> were identified. The comparator groups completed exercise sessions using treadmill training<sup>24-26</sup> and cycling training,<sup>25,28,29</sup> or completed a standard PR program consisting of both aerobic and strength training.<sup>27</sup>

Results of the risk of bias assessment are provided in Table 2. The conference abstract by Makhbah et al<sup>29</sup> was unclear in all categories of bias assessment, with no further information obtained from the authors. Of the remaining 5 studies, 4 were determined to be unclear in the blinding of study participants. Other sources of bias included limited washout periods and short exercise sessions in crossover trials. The majority of studies used appropriate randomization and reported all outcomes.

### INTERVENTION

Table 3 describes the characteristics of the active video games discussed in this review. Four studies used Nintendo Wii<sup>25,27-29</sup> and 2 used the Xbox Kinect gaming consoles.<sup>24,26</sup> Wii Fit, a game consisting of yoga, strength, and aerobic exercises, was used in 2 studies for participants with COPD<sup>29</sup> or mixed respiratory diseases.<sup>27</sup> Two crossover studies for

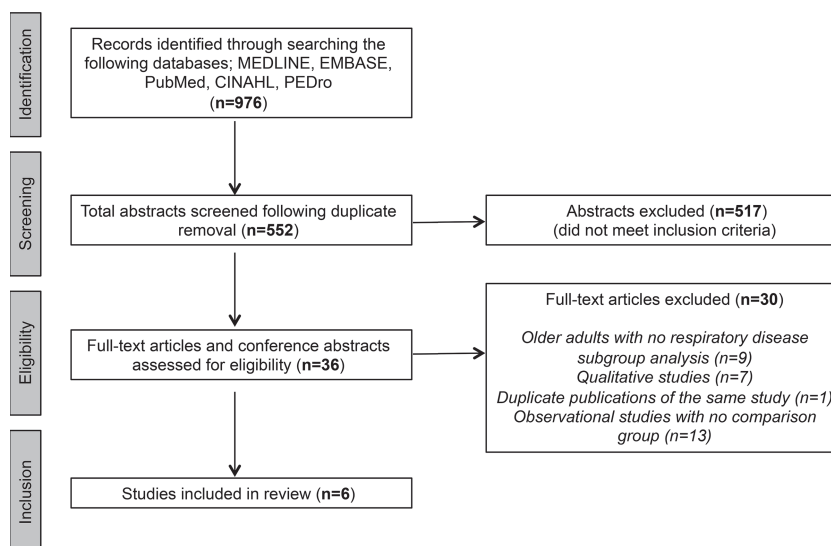


Figure. Study flow diagram from identification of studies to final inclusion.

Table 1

## Overview of Included Studies and Exercise Interventions

Studies	Population	Video Game Intervention	Control Group	Outcome Measures	Key Findings
<i>Randomized controlled trials</i>					
Gomes et al <sup>24</sup> (2015)	Asthma (n = 36) Control: n = 20 Age = 7.5 ± 1.9 y Intervention: n = 16 Age = 8.0 ± 2.0 y	Xbox Kinect Adventures "Reflex Ridge" 2×/wk for 8 wk (40-min sessions)	Treadmill	EC: Treadmill time and distance, HR Other: Energy expenditure	Control group improved treadmill distance (m) compared to VGG (895.8 ± 143.4, 703.3 ± 148.3, <i>P</i> < .05). VGG had higher total energy expenditure (cal) (159.9 ± 41.6, 133.3 ± 32.1, <i>P</i> < .01) and higher % predicted maximal HR (103.2 ± 8.6 vs 96 ± 7.80, <i>P</i> < .05)
Makhabah et al <sup>29</sup> (2015)	COPD (n = 20)	Wii Fit 2×/wk for 6 wk	Cycle	EC: 6MWT Other: Dyspnea (MRC, Borg, BDI/TDI), HRQOL (SGRQ)	VGG showed improvements in 6MWD, dyspnea, and HRQOL
<i>Short-term randomized controlled trials</i>					
Mazzoleni et al <sup>27</sup> (2014)	CRD-COPD, ILD, asthma, bronchiectasis, RCD (n = 40) Control: n = 20 Age = 68.9 ± 11.0 y Intervention: n = 20 Age = 73.5 ± 9.2 y	Wii Fit 1× daily for 1/wk (1-hr sessions)	PR alone	EC: 6MWT, Leg/arm cycle ergometry Other: Dyspnea (MRC, Borg scale, BDI/TDI), HRQOL (SGRQ), Acceptability Questionnaire	VGG showed greater improvement from baseline to end of program in 6MWD, m ( $\Delta$ = 97.4 ± 64.8, 61.1 ± 28.3, <i>P</i> < .05) and TDI ( $\Delta$ = 3.9 ± 1.9, 2.2 ± 1.0, <i>P</i> < .001)
<i>Crossover studies</i>					
Kuys et al <sup>25</sup> (2011)	Cystic fibrosis (n = 19) Age = 28 ± 7 y	EA Sports Wii Active 1× (15-min session)	Treadmill/ Cycle	EC: HR Other: SpO <sub>2</sub> , dyspnea (Borg), RPE, energy expenditure, enjoyment, fatigue	VGG had higher maximum training HR (beats/min) (VGG minus control = 9, 95% CI = 3-15).
Legear et al <sup>26</sup> (2016)	COPD (n = 10) Age = 65.0 ± 8.7 y	EA Sports Wii Active 1× (15-min session)	Treadmill	EC: HR Other: SpO <sub>2</sub> , dyspnea (Borg), RPE, energy expenditure, enjoyment, fatigue	No significant difference in outcome measures between groups.
Salonini et al <sup>28</sup> (2015)	Cystic fibrosis (n = 30) Age = 12 ± 2.5 y	Xbox Kinect Adventures "River Rush" 1× (20-min session)	Cycle	EC: HR Other: SpO <sub>2</sub> , dyspnea (VAS), enjoyment, fatigue	VGG had lower levels of dyspnea (VAS) (3, IQR: 2-5 vs 4, IQR: 3-6, <i>P</i> < .001) and fatigue (3, IQR: 2-4 vs 4.5 IQR: 3-7)

Abbreviations: BDI/TDI, Baseline/Transition Dyspnea Index; COPD, chronic obstructive pulmonary disease; CRD, chronic respiratory disease; EC, exercise capacity; HR, heart rate; HRQOL, health-related quality of life; ILD, interstitial lung disease; IQR, interquartile range; MRC, Medical Research Council; PR, pulmonary rehabilitation; RCD, restrictive chest disease; RPE, rating of perceived exertion; SGRQ, St George's Respiratory Questionnaire; 6MWT, 6-min walk test; SpO<sub>2</sub>, peripheral oxygen saturation; VAS, visual analog scale; VGG, video game group.

participants with COPD<sup>28</sup> or CF<sup>25</sup> used the EA Sports Wii Active game, consisting of jogging on the spot, dance, boxing, and other sports. Both studies using the Xbox system chose 1 mini-game from the Xbox Kinect Adventures game.

Of the randomized controlled trials, 2 studies delivered the video game intervention twice weekly for a period of 6<sup>29</sup> to 8<sup>24</sup> wk, and 1 study delivered the intervention once daily for 7 d during the last week of PR.<sup>27</sup> The length of the video game intervention ranged from 40 min<sup>24</sup> to 1 hr.<sup>27</sup> This differs from the 3 crossover studies, 2 of which included only a single 15-min session,<sup>25,26</sup> the third being a single 20-min session.<sup>28</sup>

### PRIMARY OUTCOME-EXERCISE CAPACITY

All 6 studies included outcome measures related to exercise capacity (Table 1). These included constant treadmill time and distance,<sup>24</sup> 6-min walk distance (6MWD),<sup>27,29</sup> cycle ergometry,<sup>27</sup> and measures of HR.<sup>24-26,28</sup>

Treadmill time and distance were compared for children with moderate to severe asthma following 8 wk of training using a treadmill or the "Reflex Ridge" mini-game.<sup>24</sup> Both

groups showed significant improvement in treadmill time and distance. Between-group differences favored the conventional training group (*P* < .05).

The addition of Wii Fit training to the final week of a standard PR program was associated with significant improvements in 6MWD compared with control (*P* = .028) but no difference in measures of incremental arm (*P* = .361) or leg cycle ergometry (*P* = .776) between groups.<sup>27</sup> Another study using Wii Fit noted significant improvements in 6MWD from baseline for both groups,<sup>29</sup> with no between-group differences reported.

Maximal HR levels during active video game training were comparable to or higher than those achieved by the control group in all studies.<sup>24-26,28</sup> Kuys et al<sup>25</sup> reported significantly higher minimum and maximal training HR in the video game group, although there was no difference in average HR between groups (95% CI, 3-9 beats/min).<sup>25</sup> A significantly higher percentage of predicted maximal HR during active video game training compared with treadmill training was also reported in patients with asthma (*P* < .05).<sup>24</sup>

Table 2

## Quality Assessment Results

Studies	Randomization	Allocation Concealment	Blinding			Incomplete Outcome Data	Selective Reporting	Other Bias
			Participants and Personnel	Outcome Assessor				
Gomes et al <sup>24</sup> (2015)	Low	Low	Unclear	Low	High	Low	None	
Kuys et al <sup>25</sup> (2011)	Low	Low	High	Low	Low	Low	Low: Exercises on separate days	
Legear et al <sup>26</sup> (2016)	Low	Unclear	Unclear	Unclear	Low	Low	Low: 15-min washout period	
Makhahah et al <sup>29</sup> (2015)	Unclear	Unclear	Unclear	Unclear	Unclear	Unclear	Insufficient information provided	
Mazzoleni et al <sup>27</sup> (2014)	Unclear	Unclear	Unclear	Unclear	Low	Low	None	
Salonini et al <sup>28</sup> (2015)	Low	Low	Unclear	Low	Low	Low	Low: Exercises on separate days	

**SECONDARY OUTCOME MEASURES**

Secondary outcome measures included measures of SpO<sub>2</sub>,<sup>25,26,28</sup> dyspnea rating,<sup>25-29</sup> rating of perceived exertion,<sup>25,26</sup> energy expenditure,<sup>24,26</sup> HRQOL,<sup>27,29</sup> enjoyment, and preference for exercise modality.<sup>25,26,28</sup>

**SECONDARY OUTCOME MEASURES: TRAINING**

SpO<sub>2</sub> was similar during training between all intervention and control groups and remained >90%, or was maintained with supplemental oxygen at safe levels during training.<sup>25,26,28</sup> Dyspnea levels were recorded during training using the Borg scale<sup>25,26</sup> and a visual analog scale<sup>28</sup> in the crossover studies. The Transition Dyspnea Index,<sup>27,29</sup> and the Medical Research Council dyspnea scale<sup>27</sup> were used for the randomized controlled trials. Dyspnea levels and rating of perceived exertion between groups were comparable in all studies.<sup>25,28,29</sup> Fatigue was measured in 2 studies using a visual analog scale<sup>25,28</sup>; in 1 study, Wii training resulted in similar fatigue levels compared with control<sup>25</sup>; in a second study, Xbox Kinect training was associated with significantly lower fatigue levels during training ( $P < .001$ ).<sup>28</sup>

Total energy expenditure, as measured continuously during training by a portable activity monitor, was higher than conventional exercise training only when playing the Xbox Kinect Adventure "Reflex Ridge" mini-game than during treadmill training ( $P < .01$ ),<sup>24</sup> with no differences noted with EA Sports Wii Active training.<sup>25,26</sup>

**SECONDARY OUTCOME MEASURES: CLINICAL**

Only 1 study<sup>27</sup> reported significant differences in dyspnea rating using the Transition Dyspnea Index, with the video game group reporting less breathlessness than the control group ( $P < .001$ ). Two studies<sup>27,29</sup> measured HRQOL using the St George's Respiratory Questionnaire. Both groups had significant improvement in their St George's Respiratory Questionnaire scores only from baseline to the end of the study.<sup>27,29</sup>

Enjoyment and preference for exercise modality were reported in the 3 crossover studies.<sup>25,26,28</sup> Adults with CF expressed higher levels of enjoyment for the EA Wii Sports Active games compared with treadmill exercise (95% CI, 1.6-3.6).<sup>25</sup> Children and adolescents with CF preferred

Table 3

## Active Video Game Characteristics

Studies	Game	Exercises	Exercise Type	Exercise Intensity
Gomes et al <sup>24</sup> (2015)	Xbox Kinect Adventures mini-game "Reflex Ridge"	Jumps, squats, perform lateral and arm movements to dodge obstacles and collect points 10 × 3-min rounds with a 30-sec rest interval between rounds	Aerobic lower body	90.5% of predicted maximum HR Meets recommendations of >80% predicted maximum HR for children with respiratory disorders <sup>30</sup>
Kuys et al <sup>25</sup> (2011)	EA Sports Wii Active	Boxing, running/track, dancing tailored to each participants preferences and limitations	Aerobic upper body	73% of predicted maximum HR Meets recommendations for those with low to average fitness levels <sup>31</sup>
Legear et al <sup>26</sup> (2016)	EA Sports Wii Active	"Run (medium)"—marching on the spot "Dance basic 1"—Basic arm movements "Heavy" bag—repeated punching on-screen punching bag "Targets 1"—air punching targets on-screen	Aerobic upper body	Participants self-adjusted to maintain Borg dyspnea scale of 3-5
Makhahah et al <sup>29</sup> (2015)	Wii Fit	Yoga, strength training, aerobic	Aerobic strength	No guidelines for intensity reported
Mazzoleni et al <sup>27</sup> (2014)	Wii Fit	5 min of "Yoga" (stretch and deep breathing) at the beginning and end as a warm-up/cooldown "Jogging Plus"—10-min running on the spot "Twisting and squat"—10-min twisting trunk and leg squatting as directed	Aerobic lower body	No guidelines for intensity reported
Salonini et al <sup>28</sup> (2015)	Xbox Kinect Adventures mini-game "River Rush"	Stand on a virtual raft, jump or step left or right to dodge obstacles and collect points 3 levels, each lasts 6 min with a 1-min rest in-between levels	Aerobic lower body	Aim of >80% of predicted maximum HR <sup>32</sup> Achieved by 40% of participants

Abbreviation: HR, heart rate.



the Xbox Kinect Adventures mini-game “River Rush” to stationary cycle exercise ( $P < .001$ )<sup>28</sup> while individuals with COPD equally enjoyed treadmill/cycle training and Nintendo Wii training.<sup>26</sup>

## DISCUSSION

A variety of active video games and gaming systems were used in the studies included in this review. These games varied in their exercise intensity, as reflected by the percent predicted maximum HR determined for each population.<sup>24,25,28</sup> Compared with treadmill or cycling training, active video games induced similar maximal HR<sup>24-26,28</sup> and dyspnea levels.<sup>25,26,28,29</sup> Although 1 study<sup>27</sup> reported between-group differences in 6MWD in favor of the video game intervention, the short (1 wk) intervention period limits any meaningful interpretation of the result beyond a 3-wk inpatient PR program.

The longest duration of active video game training was 8 wk with training twice weekly,<sup>24</sup> the minimum time generally recommended for exercising populations.<sup>6,31,32</sup> Only 2 of the 3 randomized controlled trials reported 6 to 8 wk of active video games versus the alternative traditional exercise training. The third randomized controlled trial had only a 1-wk add-on to a short (3-wk) PR program. Other studies varied in intervention length, the shortest 2 being a single 15-min session.

Both active video games such as Nintendo Wii EA Sports Active<sup>26</sup> and the Xbox Kinect Adventures “Reflex Ridge” and “River Rush” mini-games<sup>24,28</sup> can achieve exercise intensities similar to those achieved using treadmill or cycle training. These findings are consistent with the recent review of active video game training in patients with CF.<sup>33</sup> The style of video game training, using short, 3-5 min mini-games, with approximately 15-30 sec rest while the next game loads,<sup>26</sup> is similar to interval training, an approach used for patients with chronic respiratory diseases who may be unable to tolerate continuous exercise.<sup>34</sup> Further information is required regarding the relative intensity of exercise prescription for this approach due to the variation of games used in this review.

The specificity of training within the active video game may influence outcome measures. For example, one would not expect changes in arm cycle ergometry from a video game that was predominantly focused on lower limb training.<sup>27</sup> Similarly, the improvement in treadmill time in the control group in the study by Gomes et al<sup>24</sup> is not surprising, despite the higher training energy expenditure and HR in the video game group, as the latter involved a program of jumps, squats, and arm movements to avoid obstacles whereas the former used treadmill training. In addition, the study by Mazzoleni et al<sup>27</sup> included a measurement of HRQOL after a 1-wk long trial. This highlights the importance of evaluation studies selecting outcomes appropriate to the intervention. In addition, the comparator exercise was variable between studies both in duration and intensity and did not reflect the interval style of the video games.

The majority of active video games on the market are designed to appeal to children and young adults, but studies with older adults have demonstrated that they too can enjoy these games.<sup>11,20,26</sup> In this review, children and adults with asthma or CF clearly preferred video game training<sup>24,28</sup> whereas adults with COPD enjoyed both training modalities.<sup>26</sup> Active video games are a unique exercise training option as they offer the enjoyment and competitive aspect of video games but are controlled by the player’s movement and, therefore, are also a form of physical activity. By immersing the player in a virtual reality, active video

games also serve to distract the player from symptoms such as fatigue or dyspnea, common among the respiratory population.<sup>25,26,28,29</sup>

While the collective results demonstrating similar training maximal HR, dyspnea levels and positive enjoyment are encouraging, longer-term studies, with a consistent intervention in a homogeneous population, are required to establish the clinical impact of active video game training. In addition, personnel should be blinded to group allocation when evaluating outcome measures to reduce the risk of bias in future studies. Given the nature of the intervention, it would be difficult to blind participants. An important limitation of this review is the small number of studies identified, which reflects the novelty of video game training in respiratory rehabilitation. Had this review been expanded to include a cardiac population, there would have been more studies included; however, a comprehensive review of “exergames” in cardiac rehabilitation has been previously published.<sup>35</sup> The small number of studies identified included methodological limitations relating to the small sample size, heterogeneity, and duration of exercise training. Such variations in the study design, population, intervention, and outcome measures prevented grouping of data in a meta-analysis. Therefore, current evidence is insufficient to establish the role of active video game training for individuals with chronic respiratory diseases. However, this review will help inform further studies in this area. If shown to be a clinically useful component of exercise, active video games could provide additional variety to standard PR exercise training, increasing motivation and promoting adherence<sup>17,20</sup> both in a hospital setting<sup>20,24,27</sup> and at home.<sup>14,17,18</sup>

## CONCLUSION

Active video games can induce similar physiological demands such as maximal HR, dyspnea levels, and energy expenditure during training as traditional exercise modalities. The evidence of enhanced clinical outcomes provided in this review is of low quality with small sample sizes and brief intervention periods. Larger randomized controlled trial of homogeneous design and longer-term follow-up will determine whether active video game training can result in long-term improvements in exercise capacity and HRQOL among those with chronic respiratory conditions.

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