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Original Article

Xbox Kinect™ represents high intensity exercise for adults with cystic fibrosis

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Abstract

Background: Exercise is important for patients with cystic fibrosis (CF). Interactive gaming consoles are a new trend in exercise. This study sought to determine the exercise intensity of training using the Xbox Kinect™.
Methods: Participants with CF completed two sessions separated by ≤ 10 days. The first session involved a cardiopulmonary exercise test (CPET) to measure peak exercise capacity. The second session involved 20 min of exercise using the Xbox Kinect™.
Results: Ten participants (median [interquartile range] FEV_1 58 [46]%, 29 [6] years, 6 males) completed the study. The average heart rate over the final 10 min of exercise using the Xbox Kinect™, expressed as a percentage of the peak heart rate achieved on the CPET, was 86% (95% confidence interval, 81 to 92%).
Conclusions: Training using the Xbox Kinect™ represents high intensity exercise for adults with CF and may be a suitable alternative to conventional exercise modalities.

Keywords: Cystic fibrosis; Exercise; Interactive gaming console

1. Introduction

Cystic fibrosis (CF) is an inherited chronic lung disease characterised by the production of mucous secretions and recurrent respiratory infections [1]. The most prevalent symptoms are cough, dyspnoea and lack of energy [2], all of which compromise exercise tolerance. Nevertheless, in people with CF, exercise tolerance improves with structured exercise training. Specifically, whole body exercise such as walking/running, cycling and swimming has been demonstrated to increase the peak rate of oxygen uptake ($\dot{V}O_2$ peak) [3] as well as reduce heart rate (HR) and lactate concentrations at sub-maximal exercise intensities [4]. Exercise training also improves health-related quality of life [5] and is used to promote airway clearance [6].

Despite these benefits, adherence to exercise training programs is often problematic. Earlier work suggests that the proportion of adults with CF who were adherent with treatment, which included exercise training, was as low as 24% [7]. Poor adherence with exercise programs has been implicated in more frequent exacerbations and increased hospital admissions and, therefore, strategies are needed to overcome the perceived barriers to exercise [8]. The most commonly reported barriers to exercise in this population are physical discomfort and boredom with traditional forms of exercise [9]. Therefore, alternative modes of exercise are needed which are both enjoyable and

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capable of yielding physiological adaptations. Alternative exercise modalities such as the use of interactive gaming consoles may optimise adherence due to the greater levels of enjoyment [10].

To date, only one study has explored the utility of interactive gaming consoles in the CF population. This study compared the cardiovascular demand of exercise using the Nintendo Wii™ with that measured during standard cycle or treadmill exercise [10]. The results demonstrated that exercise using the Nintendo Wii™ elicited similar cardiovascular demands to standard exercise modalities. Of note, using the interactive gaming console was associated with greater enjoyment [10], which is likely to improve adherence with exercise. Nevertheless, as peak exercise capacity was not measured in this study, the intensity of exercise achieved when using an interactive gaming console, relative to an individual's peak, could not be determined.

The primary aim of this study was to determine the intensity of exercise achieved when using an interactive gaming console, relative to that measured during a cardiopulmonary exercise test (CPET) in adults with CF. We also sought to describe the pattern of cardiorespiratory response during exercise using the Xbox Kinect™ compared to that observed during the CPET.

2. Methods

2.1. Design and ethics approval

This prospective, two-visit observational and cross sectional study was approved by the relevant Human Research Ethics Committees (approval numbers EC 2011/111, HR177/2011 and 2011-127). Written, informed consent was obtained from each individual prior to participation.

2.2. Participants

Inclusion criteria comprised a diagnosis of CF and aged over 18 years. Exclusion criteria comprised any known co-morbid condition(s) thought to adversely affect performance during testing (for example, musculoskeletal pain), the need for supplemental oxygen during exercise, previous heart or heart–lung transplant, an inability to communicate in English, airway colonisation with *Burkholderia cepacia* or active methicillin-resistant *Staphylococcus aureus*, or any history of marked claustrophobia as the study required wearing a mask or mouthpiece and nose peg during the CPET.

2.3. Protocol

Each participant attended two 60 minute assessment sessions, separated by at least 24 h and no more than 10 days. The sessions took place at the same time of day and bronchodilator use was standardised between assessment sessions. During the first assessment session age, gender, height and weight were recorded. Spirometric measures of lung function were obtained (EasyOne; NDD Medical Technologies; Massachusetts; USA) and expressed as a percentage of the predicted value for healthy individuals [11]. The forced expiratory volume in one second (FEV_1) and forced vital capacity (FVC) were recorded as the best of three attempts. Thereafter, each participant undertook a laboratory-based CPET on an electronically braked cycle ergometer (Lode Corival 906900; Lode B.V. Medical Technology; Groningen; The Netherlands). The cycle ergometer was chosen as it is the most common laboratory-based CPET used in adults with respiratory disease [12]. The second assessment session required the participant to complete 20 min of exercise using the Xbox Kinect™ (Microsoft Corporation; Redmond; WA; USA).

During both the assessment sessions, arterial oxygen saturation (SpO_2) was recorded continuously using a pulse oximeter attached to a forehead sensor (Masimo Rainbow Radical 7; Masimo Corporation; California; USA). Dyspnoea and perception of exertion were measured each minute for the duration of exercise using the Borg category ratio scale and the six to 20 Rating of Perceived Exertion (RPE) scale, respectively [13]. Following completion of each assessment session, leg fatigue was reported using the Borg category ratio scale [13].

2.4. Assessment sessions

2.4.1. CPET

Participants pedalled without load for one minute and thereafter the rate at which the work rate increased was individualised (10, 15 or 20 $W \cdot min^{-1}$) with the goal of achieving symptom-limitation in eight to 12 min [14]. Participants were instructed to refrain from talking during this test and were provided with strong verbal encouragement to achieve the highest work rate possible.

Expired gas analysis during the CPET allowed for breath by breath measures to be collected of the rate of oxygen uptake $\left(\dot{V}O_2\right)$ and minute ventilation. Heart rate (HR) was continuously recorded using a 12 lead electrocardiogram. Maximum voluntary ventilation (MVV) was estimated using the FEV_1 measured immediately post-exercise multiplied by 35 [15].

2.4.2. Xbox Kinect™ exercise

The Xbox Kinect™ exercise session involved repetitive cardiovascular-based interval training, comprising alternating sets of squat punches and jumping jacks using the Your Shape™ Fitness Evolved program. This program was selected as it required only basic coordination and was designed for adult users. It simulates an exercise class in a gymnasium environment with a personal trainer and offers a range of activities such as boxing, yoga, dance and other aerobic programs with increasing levels of difficulty. Participants were naïve to this specific program and were permitted to sit and rest during this session if symptoms became intolerable, with encouragement to recommence exercise as soon as they felt it was possible. During this session, HR was measured continuously and recorded every minute from a Polar HR monitor (Polar Electro; Kemple; Finland).

2.5. Data analysis

Data analysis was undertaken using Statistical Package for Social Science (SPSS version 19.0; SPSS inc.; Chicago; IL; USA) and Sigmaplot® (version 12.0; Systat Software Inc.). Data are presented as median [interquartile range] unless otherwise stated. Probability (P) values ≤ 0.05 were considered significant.

To report the intensity of exercise achieved using the Xbox Kinect™ we expressed the intensity as a percentage of the peak HR measured during the CPET. To do this, we determined the average HR elicited during final 10 min of exercise using the Xbox Kinect™. The first 10 min of data were excluded as participants were considered to be warming up and familiarising themselves with the interactive gaming console. The average HR achieved during the Xbox Kinect™ was expressed as a percentage of peak HR measured during the CPET and this variable approached a normal distribution. The group mean and 95% confidence interval (CI) were calculated.

We also expressed intensity of exercise in terms of metabolic equivalents (METS). To do this, for each participant, we used linear regression analysis to establish the relationship between HR (independent variable) and $\dot{V}O_2$ (dependent variable) measured during the CPET. Thereafter, the average HR over the final 10 min of exercise using the Xbox Kinect™ was entered into this regression equation to estimate $\dot{V}O_2$ achieved using the interactive gaming console. METS were then derived by dividing the estimated $\dot{V}O_2$ (expressed in $ml \cdot kg^{-1} \cdot min^{-1}$) by 3.5.

Cardiorespiratory responses both within (i.e. rest vs. end-exercise) and between exercise modalities (i.e. CPET vs. Xbox Kinect™) were compared using Wilcoxon tests.

Table 1
Participant characteristics (n = 10; 6 male).

Variable	Median [IQR]	Range
Age (yr)	29 [6]	21 to 51
Height (cm)	174 [17]	150 to 190
Weight (kg)	66.1 [9.5]	38.9 to 75.2
BMI (kg/m^2)	22.0 [3.5]	17.0 to 24.0
FEV_1 (L)	2.04 [1.42]	1.39 to 4.36
FVC (L)	3.53 [1.16]	2.00 to 5.67
FEV_1 (% predicted)	58 [46]	31 to 97
FVC (% predicted)	74 [30]	51 to 105
FEV_1/FVC (%)	68 [27]	42 to 80

BMI = body mass index, FEV_1 = forced expiratory volume in one second, FVC = forced vital capacity.

2.6. Sample size calculations

Given that we were using HR to determine exercise intensity, we sought to detect a difference in peak HR achieved during the CPET and the average HR recorded over the last 10 min of using the Xbox Kinect™ of 15 ± 15 bpm. A sample size of 10 participants would yield adequate power ($\alpha = 0.05$; $1 - \beta = 0.8$) to detect a difference of this magnitude.

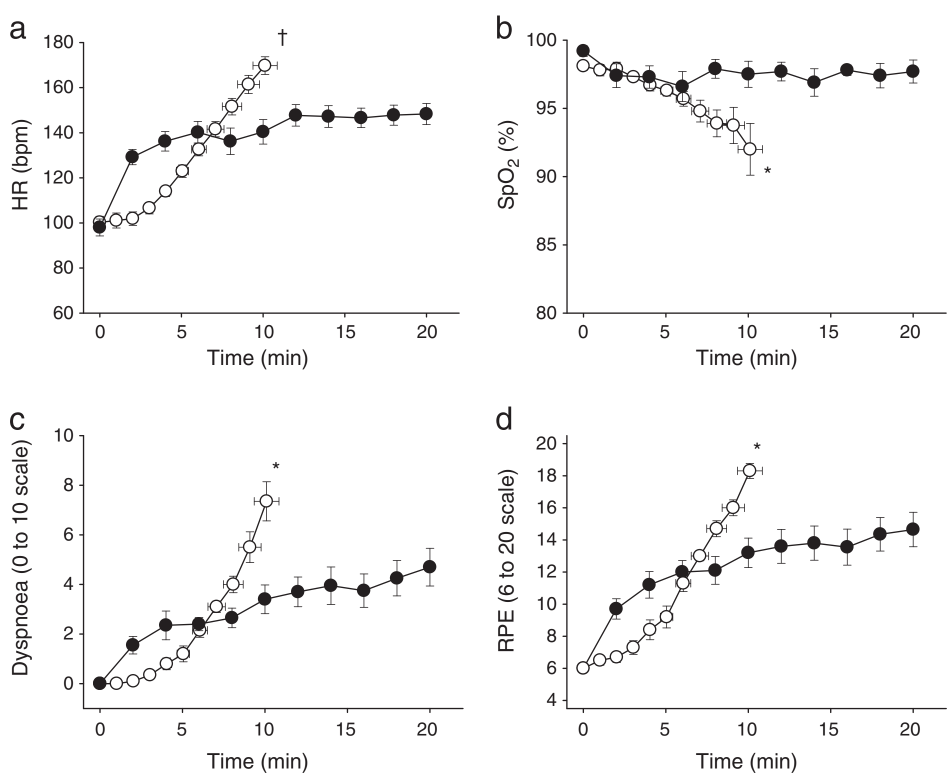

Fig. 1. A comparison of cardiorespiratory responses between the CPET and training on the Xbox Kinect™. Data are mean and standard error of the mean. All participants contribute to each data point. Figures are patterns of response for; (a) heart rate (HR), (b) arterial oxygen saturation measured via pulse oximetry (SpO_2), (c) dyspnoea measured using the Borg 0 to 10 scale and (d) rating of perceived exertion (RPE) measured using the 6 to 20 RPE scale. ○, cardiopulmonary exercise test (CPET); ●, Xbox Kinect™; *: $P < 0.05$ and †: $P < 0.01$ for difference between CPET and Xbox Kinect™. To compare peak responses, given the steady state responses of HR and SpO_2, data were averaged over the final 10 min of the Xbox Kinect™ exercise. As dyspnoea and RPE did not show steady state responses, measures reported at the end of the exercise session are presented.

3. Results

All 10 participants who provided informed consent completed the study. No adverse events occurred during either assessment session. Characteristics of the participants are summarised in Table 1.

The CPET lasted between 7 and 15 min, with the limiting factor being either dyspnoea (n = 6; 60%) or leg fatigue (n = 4; 40%). Peak HR achieved on completion of the CPET, expressed as a percentage of the maximum estimated using age (i.e. 220 − age [yr]) was (median [interquartile range]) 90 [6]%. The peak level of ventilation achieved during the CPET, expressed as a proportion of the MVV was equivalent to 90 [63]%.

During exercise on the Xbox Kinect™, three (30%) participants required unscheduled rests. These participants took between 2 and 5 rests, which lasted between 34 s and 2 min. Mean HR achieved during the final 10 min of the Xbox Kinect™, expressed as a percentage of the maximum estimated using age (i.e. 220 – age [yr]) was 76 [14]%.

The mean intensity of exercise elicited during the Xbox Kinect™, expressed as a percentage of the peak HR achieved on the CPET, was 86% (95% CI, 81 to 92%). Individual responses ranged between 73 and 96%. Using the regression equations, HR alone explained between 93 and 100% of the variance in $\dot{V}O_2$. The exercise intensity achieved using the Xbox Kinect™, estimated using these regression equations, was equivalent to 6.1 [1.8] METS.

Fig. 1a–d presents the cardiorespiratory responses to exercise during the CPET and using the Xbox Kinect™. Regarding peak responses, when compared with the Xbox Kinect™, greater values were achieved during the CPET for HR, dyspnoea, and RPE. Greater desaturation was noted during the CPET compared with the Xbox Kinect™. On completion of the CPET, leg fatigue was greater (7 [4]) when compared with the Xbox Kinect™ (2 [2]) (p = 0.020).

4. Discussion

This is the first study to determine the exercise intensity of using the Xbox Kinect™ in adults with CF relative to peak exercise capacity measured during a laboratory-based CPET. The most important finding of this study was that training using the Xbox Kinect™ elicited an exercise intensity equivalent to 86% (95% CI, 81 to 92%) of maximum. This was equivalent to 6.1 [1.8] METS.

Our data demonstrating that training using the Xbox Kinect™ constitutes high exercise intensity has important implications for clinical practice. Although there are limited data to guide optimal exercise prescription for adults with CF, pulmonary rehabilitation guidelines state that a training intensity equal to at least 60% of an individual's peak exercise capacity is needed to confer a physiological adaptation [16]. Similarly, the American College of Sports Medicine states that the minimal training intensity needed for healthy individuals with low levels of fitness to achieve an improvement in aerobic capacity is 55 to 65% of maximum HR [17]. Our data revealed that individual exercise intensities using the Xbox Kinect™ ranged between 73 and 96% of peak HR, thereby exceeding the minimal threshold required to induce a training adaptation. In those individuals who require unscheduled rests due to intolerable symptoms whilst exercising using the Xbox Kinect™, implementation of an interval-based training approach characterised by more frequent rests would optimise the likelihood that the training intensity is not compromised. The Your Shape™ Fitness Evolved program appears to be feasible into adulthood, as demonstrated by completion of this program by a 51 year old. These results support this program as a form of high intensity aerobic exercise for adults with CF. However, further study would be necessary to determine the exercise intensity of other Xbox Kinect™ programs.

The use of interactive gaming consoles in the management of people with a chronic health condition is an evolving area of research. Interactive games have been explored in a variety of patient populations including children with developmental delay [18] and with cerebral palsy [19]. They have also been used to facilitate the rehabilitation of adults following total knee replacement [20] as well as people with Parkinson's disease [21]. Interest in their use for people with chronic respiratory disease is increasing [22,23] however, to date, only one study has investigated their use in people with CF [10]. Our results support those of Kuys et al. [10] who reported that exercise intensity using the Nintendo Wii™ was equivalent to 73% of peak HR or 6.5 METS in this population. However, this earlier study has important methodological shortcomings that limit the validity of their conclusions. Specifically, energy expenditure was measured using a Sensewear Pro activity monitor; a device which underestimates energy expenditure at high exercise intensities [24]. Further, the Sensewear Pro activity monitor has not been validated to assess energy expenditure associated with arm exercise [25] and the exercises undertaken in the study by Kuys et al. [10] predominately worked the upper limbs (e.g. boxing). In contrast, we derived our estimate of exercise intensity using direct measures of HR and $\dot{V}O_2$ obtained via expired gas analysis during the CPET, which is considered a gold standard. We are therefore confident that our estimate of the intensity of exercise achieved using the Xbox Kinect™ is robust.

Our data comparing cardiorespiratory responses indicates that although Xbox Kinect™ training is equivalent to high intensity exercise, it elicited responses that were significantly less than those achieved during maximum exercise testing. Cardiorespiratory responses during the CPET were characterised by a curvilinear pattern of change. In contrast, cardiorespiratory responses during exercise using the Xbox Kinect™ were characterised by an exponential change in response over the first half of the test, followed by a relative plateau, reflecting steady-state sub-maximal exercise. Of note, desaturation was less pronounced during exercise using the Xbox Kinect™ compared with that measured during the CPET. This finding contrasts with that previously reported in people with chronic obstructive pulmonary disease (COPD) who demonstrate significantly greater desaturation during whole-body exercise such as walking [26,27], compared with cycle exercise. The trivial desaturation during exercise using the Xbox Kinect™ contributes to the safety profile of this modality.

The main limitation of this study was performing the laboratory-based test on a cycle ergometer rather than a treadmill. Although healthy individuals will achieve a greater maximum $\dot{V}O_2$ during whole-body exercise compared with cycling, this difference is negligible in people with chronic lung disease who have ventilatory limitation during exercise [28]. Further, we did not collect measures of $\dot{V}O_2$ during exercise using the Xbox Kinect™. However, the relationship between HR and $\dot{V}O_2$ was established for all participants and the regression equations used to estimate $\dot{V}O_2$ from HR explained at least 93% of the variance. The modest sample size also limits the precision and therefore generalisability of our results. However, the 95% CI around our estimate of exercise intensity elicited during exercise using the Xbox Kinect™ was narrow, being 81 to 92%. Further study is needed to determine the effect of training using the Xbox Kinect™ on exercise capacity in adults with CF and whether or not this form of exercise confers greater adherence with exercise.

5. Conclusion

The emergence of interactive gaming consoles has created new trends in exercise, which allow for exercise to be completed all year round in the convenience of an individual's own home. Our study has demonstrated that training using the Your Shape™ Fitness Evolved program for Xbox Kinect™ is of high intensity, and is therefore likely to be a suitable alternative to conventional exercise modalities, such as treadmill and cycle-ergometry exercise to improve aerobic capacity in adults with CF.

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