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Gaming console exercise and cycle or treadmill exercise provide similar cardiovascular demand in adults with cystic fibrosis: a randomised cross-over trial

Suzanne S Kuys1,2, Kathleen Hall3, Maureen Peasey3, Michelle Wood3, Robyn Cobb3 and Scott C Bell3,4

1Allied Health Research Collaborative, Metro North (Northern) Health Service District, 2 School of Physiotherapy and Exercise Science, Griffith University, 3Adult Cystic Fibrosis Centre, The Prince Charles Hospital, 4 School of Medicine, University of Queensland, Queensland, Australia

Introduction

Exercise is recognised as an important component of overall treatment for people with cystic fibrosis (Bradley and Moran 2008, Hebestreit et al 2010, Williams et al 2010). Benefits of regular exercise in this population include enhanced muscle clearance (Salh et al 1989, Bilton et al 1992), increased respiratory muscle endurance, decreased breathlessness (O’Neill et al 1987), and increased cardiorespiratory fitness (Hebestreit et al 2010, van Doorn 2010, Shoemaker et al 2008). Other reported benefits include improved body image through increased muscle mass and strength (Sahlberg et al 2008) and promotion of emotional well being and perceived health (Selvadurai et al 2002, Hebestreit et al 2010). With a lack of exercise training potentially leading to increasing severity of lung disease and a reduced ability to perform everyday tasks (Bradley and Moran 2008), it is imperative that strategies to maximise adherence with treatment regimens are investigated.

Adults with cystic fibrosis typically have low long-term adherence to their often complex treatment regimen, including chest physiotherapy and exercise, despite being aware of its importance (Myers 2009). Various factors have been shown to influence adherence to both exercise and chest physiotherapy including the degree to which a person is worried about their disease (Abbott et al 1996), their gender, the perceived burden of the treatment (Myers 2009), being too busy, and not being bothered (White et al 2007). Strategies suggested to improve adherence to exercise include incorporating regular supervision and providing an individualised exercise program that is enjoyable and to the patient’s interests and limitations (Prasad and Cerny 2002, Pendleton and David 2000), although this has received little investigation.

Exercise programs based on using a gaming console offer the potential to meet some of the challenges associated with exercise adherence in people with cystic fibrosis. One popular commercially available gaming console is Nintendo-Wii™. It comprises a suite of games and activities that involve the player in dance, martial arts, sports and other forms of physical activity. Some programs such as Nintendo-Wii™ Fit and EA Sports Wii™ Active specifically target physical fitness through a range of aerobic, balance, yoga, and strengthening activities. Nintendo-Wii™ has a wireless controller which is purported to detect movement in three dimensions. In addition, the Wii™ balance board, a component of the Wii-Fit game that contains four pressure transducers, has been shown to be a valid measure of standing balance (Clark et al 2010). Gaming console exercise provides instant visual and verbal feedback with games that are goal-oriented and enjoyable and therefore has the potential to improve motivation and adherence to an exercise program.
An exercise program using a gaming console may improve exercise adherence among people with cystic fibrosis because the exercise is purported to be fun, which may increase motivation to exercise. However, before gaming console exercise is included in an exercise program it is important to determine if it provides a similar cardiovascular demand as more traditional exercise programs. Therefore, this research sought to investigate if gaming console exercise is a feasible mode of aerobic exercise in adults with cystic fibrosis. Specifically, the research questions were:

1. Does participating in 15 minutes of exercise using a gaming console produce a similar cardiovascular demand and energy expenditure as exercise on a treadmill or cycle ergometer in adults with cystic fibrosis?
2. Is the gaming console exercise perceived as more enjoyable, less fatiguing, and achieving a similar workload as exercise on a treadmill or cycle ergometer?
3. Is the gaming console exercise perceived as equally effective and feasible for use as a regular exercise regimen as exercise on a treadmill or cycle ergometer?

**Method**

**Design**

A randomised cross-over trial with concealed allocation, intention-to-treat analysis, and assessor blinding for two outcomes was conducted at a tertiary referral public hospital in Brisbane, Australia. Participants underwent two exercise interventions in a randomised order within a 48-hour period. One intervention involved exercise using a gaming console and the other involved exercise on a treadmill or cycle ergometer. Participants were randomly allocated to the order of exercise interventions by an investigator independent of the recruitment of participants using a computer-generated random number program. Allocation was concealed with the use of consecutively numbered envelopes.

**Participants, therapists, centre**

Patients with cystic fibrosis admitted to The Prince Charles Hospital, Brisbane, for treatment of a pulmonary exacerbation were eligible to participate in this study once they were considered clinically stable, ie, had a temperature within normal limits, were not excessively breathless, and had a respiratory rate < 25 breaths/minute. Also, they were required to be able to communicate in English and to be receiving a daily physiotherapy exercise program as part of routine inpatient management. Patients were excluded if they had a cardiovascular condition prohibiting participation in an exercise program, a systemic disease affecting muscles or joints (eg, acute arthritis), recent surgery, or acute musculoskeletal pain requiring physiotherapy intervention. Demographic and clinical information collected included age, gender, and lung function.

**Intervention**

The gaming console used for the experimental intervention was the Nintendo-Wii™. The intervention incorporated interval training using the EA Sports WiiActive™ program and involved an individualised program comprising games and activities such as boxing, running/track exercises, and dancing tailored to each participant’s preferences, impairments, and activity limitations. The control intervention consisted of moderate intensity interval training using a treadmill or cycle ergometer, depending on the participant’s preference, and again tailored to each participant’s impairments and activity limitations. For both interventions, instructions were provided to participants to exercise at an intensity that resulted in some breathlessness but still allowed speech, aiming for a Borg scale score between 3 and 5. Each intervention was supervised by the same physiotherapist. Prior to each exercise intervention, participants sat quietly in a chair for 10 minutes before recording resting measures. Each exercise intervention comprised 15 minutes of exercise, including warm up and excluding rest periods and cool down. The warm up and cool down consisted of lower intensity exercise relevant to each intervention, eg, walking or slow pedaling and stretching.

**Outcome measures**

Cardiovascular demand of the two exercise interventions was measured using heart rate and oxygen saturation recorded continuously via a forehead probe with a pulse oximeter. Participant perception of the cardiovascular demand of each exercise intervention was measured using the modified Borg dyspnoea scale (Mahler et al 2001) and Rating of Perceived Exertion scale (6 to 20) (Borg 1982) to indicate breathlessness and exercise intensity respectively.

Energy expenditure during the exercise was measured using a SenseWear Pro activity monitor. The SenseWear Pro activity monitor, worn on the right upper arm, measures skin temperature, galvanic skin response, heat flux, and motion via a 2-axis accelerometer, calculating energy expenditure in metabolic equivalents (MET) during the recorded movement (Jakicic et al 2004). The SenseWear Pro activity monitor has been shown to be reasonably accurate for measuring energy expenditure during short bursts of different intensity activities in healthy adults (Berntsen et al 2010) and in adults with cystic fibrosis (Dwyer et al 2009) with the activity monitor slightly overestimating energy expenditure during low to moderate intensity activities and underestimating energy expenditure at high exercise intensities compared to indirect calorimetry (Dwyer et al 2009). Data from the activity monitor were deidentified at downloading to allow assessor blinding for average and total energy expenditure.

The participants’ perception of using a gaming console as an exercise modality was measured using a 10-cm horizontal visual analogue scale. Participants were asked to rate their level of enjoyment, fatigue experienced, and workload achieved during the exercise intervention. In addition, participants were asked to rate their confidence that the exercise intervention met their perception of an effective exercise for them and that the exercise intervention was feasible to be included as a component of their routine exercise regimen. All visual analogue scales were anchored, with the left hand anchor indicating no agreement with the statement (no enjoyment, not fatiguing, no workload, not effective, not feasible) and the right hand anchor indicating strong agreement (very enjoyable, very fatiguing, etc).

Cardiovascular demand and energy expenditure measures were recorded continuously during 5 minutes of rest at the start of the exercise interventions and during the 15 minutes of exercise. The participants’ perceptions of the exercise intervention were measured at the completion of the exercise.
Data analysis

The primary outcome was the average heart rate during exercise. We planned and undertook an analysis of the first 14 participants to determine the standard deviation of the difference between two recordings of the average heart rate during exercise in the same patient, which was 12 beats/min. In the absence of an established value, we nominated 10 beats/min as a clinically worthwhile difference in heart rate based on our clinical experience and because it exceeds day-to-day variability in heart rate (Achten and Jeukendrup 2003). Therefore, a sample size of 18 participants was required to achieve 90% power to detect a difference of 10 beats/min between the two exercise interventions at a significance level of 0.05.

All measures were analysed using an intention-to-treat analysis. Means and standard deviations were calculated for all variables. Average, minimum and maximum values were recorded for heart rate and oxygen saturation during the 5-minute rest period and the 15-minute exercise period for each exercise intervention. Average energy expenditure during the 15 minutes of exercise was estimated by the activity monitor software in metabolic equivalents (MET). Total energy expenditure for the entire exercise intervention was estimated in kilocalories by the same software. Differences in all variables between the two exercise interventions were analysed using paired t-tests. Results were reported as mean differences and 95% CI. Statistical significance was set at 0.05.
Table 1. Baseline characteristics of participants.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>n = 19</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yr), mean (SD)</td>
<td>28 (7)</td>
</tr>
<tr>
<td>Gender, n male (%)</td>
<td>10 (53)</td>
</tr>
<tr>
<td>FEV$_1$ (% pred), mean (SD)</td>
<td>51 (21)</td>
</tr>
<tr>
<td>FVC (% pred), mean (SD)</td>
<td>71 (16)</td>
</tr>
</tbody>
</table>

FEV$_1$ = forced expiratory volume in 1 sec, FVC = forced vital capacity, % pred = percentage of the predicted value

Table 2. Mean (SD) of heart rate, oxygenation and energy expenditure at rest before each exercise intervention, and during each exercise intervention, and the mean (95% CI) difference between intervention groups during exercise.

<table>
<thead>
<tr>
<th>Outcome</th>
<th>At rest</th>
<th>During exercise</th>
<th>Difference between interventions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Exp</td>
<td>Con</td>
<td>Exp minus Con</td>
</tr>
<tr>
<td></td>
<td>(n = 19)</td>
<td>(n = 19)</td>
<td>(n = 19)</td>
</tr>
<tr>
<td>Heart rate (bpm)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximum</td>
<td>102 (14)</td>
<td>101 (16)</td>
<td>9 (3 to 15)</td>
</tr>
<tr>
<td>Average</td>
<td>91 (16)</td>
<td>90 (15)</td>
<td>1 (–3 to 9)</td>
</tr>
<tr>
<td>Minimum</td>
<td>81 (16)</td>
<td>80 (15)</td>
<td>13 (2 to 24)</td>
</tr>
<tr>
<td>Oxygenation (SpO$_2$ %)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximum</td>
<td>99 (2)</td>
<td>99 (2)</td>
<td>1 (0 to 3)</td>
</tr>
<tr>
<td>Average</td>
<td>98 (2)</td>
<td>98 (2)</td>
<td>1 (0 to 2)</td>
</tr>
<tr>
<td>Minimum</td>
<td>95 (4)</td>
<td>96 (2)</td>
<td>2 (–2 to 6)</td>
</tr>
<tr>
<td>Energy expenditure (MET)</td>
<td>1.6 (0.8)</td>
<td>1.5 (0.5)</td>
<td>0.1 (–0.3 to 0.5)</td>
</tr>
</tbody>
</table>

bpm = beats per minute, SpO$_2$ % = percentage saturation of oxyhaemoglobin measured by pulse oximetry, MET = metabolic equivalents, shaded rows = primary outcomes

Results

Flow of participants through the study

Nineteen participants with cystic fibrosis admitted to inpatient care following an acute episode were recruited to this study (Figure 1). Their baseline characteristics are presented in Table 1. Ten (53%) participants undertook the control intervention (exercise using either a treadmill or cycle ergometer as prescribed by the treating physiotherapist) first. The two exercise interventions were conducted for all participants within a 48 hour period, within 72 hours of discharge. Both exercise modes were delivered by the same physiotherapist in the Physiotherapy Gym of the Adult Cystic Fibrosis Unit at The Prince Charles Hospital in Brisbane, Australia.

Cardiovascular demand

Exercise heart rate and oxygen saturation data during rest and each exercise intervention are presented in Table 2.

During the 15-minute exercise, there was no significant difference in the average heart rate between the gaming console exercise of 144 beats/min (SD 13) and control exercise of 141 beats/min (SD 15), mean difference 3 beats/min (95% CI –3 to 9). However, gaming console exercise induced a significantly higher maximum heart rate, by 9 beats/min (95% CI 3 to 15) and a significantly higher minimum heart rate, by 13 beats/min (95% CI 2 to 24). Average, maximum and minimum oxygen saturation during exercise did not differ significantly between the groups, with between-group differences of only 1–2% (absolute). Participants thought both exercise modes provided a ‘hard’ workout, rating each on average a score of about 15 on the RPE scale (Table 3).

Energy expenditure

Energy expenditure at rest and during the 15 minutes of exercise is presented in Table 2. No data were recorded for two participants, one each in both exercise interventions. There were no significant differences between the two exercise modes during the 15 minutes of exercise (1.0 MET, 95% CI –0.3 to 0.5). However, there was a significant difference between the two exercise interventions for the total energy expended in the whole exercise session (26 kcal, 95% CI 17 to 35), as presented in Table 3.

Perception of exercise

The participants’ perception of the exercise is presented in Table 3. Participants rated the gaming console exercise as significantly more enjoyable on the 10-cm visual analogue scale, mean difference 2.6 cm (95% CI 1.6 to
Participants did not perceive significantly different fatigue or workload between the two types of exercise. Participants thought both exercise modes were an effective form of exercise, rating each on average a score of about 8 on the visual analogue scale. Similarly, participants thought both exercise modes would be feasible to include as part of their regular exercise regimen, rating each on average a score of about 8 on the visual analogue scale. The amount of dyspnoea also did not differ between the two types of exercise.

Discussion

Exercise involving a gaming console appears to be a feasible mode of aerobic exercise for adults with cystic fibrosis. The cardiovascular demand, energy expenditure, perceived workload, and amount of fatigue appear to be similar between the two types of exercise. Participants reported greater enjoyment at the completion of the exercise session using the gaming console.

Aerobic exercise appears to be beneficial for people with cystic fibrosis (Shoemaker et al 2008) with some slowing of the decline in lung function (Schneiderman-Walker et al 2000). Therefore, it is worthwhile investigating exercise options – especially those that appeal to patients – to determine if they are appropriate for people with cystic fibrosis. There are three requirements for exercise to be classified as aerobic: appropriate activity, intensity, and duration (ACSM 2010). Recommended activities are those that involve large muscle groups, are rhythmic in nature such as walking or running, and last a minimum of 20 minutes in total. The gaming console used in the current study incorporates some whole body, some predominantly upper limb, and some predominantly lower limb activities. The modalities of exercise typically investigated for cystic fibrosis, on the other hand, tend to involve predominantly lower limb activities such as walking, running, and cycling (Bradley and Moran 2008). Adults with cystic fibrosis work less during arm compared to leg exercise (Alison et al 1997). However, any reduction in workload during upper limb activities in the current study appears to have been minimal or compensated for by other activities because participants rated both exercise interventions as a ‘hard’ workout with similar heart rate and energy expenditure recorded. This suggests that participants were able to achieve a comparable workload during the gaming console exercise compared to exercise using a treadmill or cycle ergometer. In fact, calculating the workload using average heart rate during each exercise intervention as a percentage of age predicted maximal heart rate, an average intensity of 73% was reached. This is a sufficient intensity for those with low to average levels of fitness (ACSM 2010) to improve aerobic fitness. This is therefore a reasonable intensity level for use with these adults with cystic fibrosis who had just recovered from a pulmonary exacerbation. However, this may not be applicable for other populations because people with cystic fibrosis have been shown to have a higher energy cost for physical activity, in particular, for walking compared to healthy controls (Richards et al 2001).

We included maximum and minimum measures in the current study to gauge the range of cardiovascular demand in both exercise interventions. In particular, maximum heart rates were monitored as is typically done during a treatment session, to ensure that excessive cardiovascular demand was not being placed on the participant. Although the average heart rate during the exercise did not significantly differ between the two types of exercise, higher minimum and maximum heart rates were recorded during the gaming console exercise. This might require monitoring if gaming console exercise is included as a treatment option for inpatients or as a component of a regular exercise program.

The greater total energy expenditure observed during the gaming console exercise might be due to the method of delivery. Gaming console exercise uses a number of different games or activities, each lasting up to several minutes. At the completion of each game, feedback is provided including a ‘score’ and verbal encouragement about the performance. During this time, no exercise is undertaken but the person remains standing. This intermittent form of exercise may account for the longer time – at least 20 minutes – required to complete the 15 minutes of exercise when using the gaming console. This had the added benefit of increasing the total time spent active and may have contributed to the greater overall energy expenditure observed during the gaming console exercise intervention. The duration of exercise used in the current study of 15 minutes was not sufficient to meet the requirements for aerobic training. However, as fatigue levels were recorded at only about 5 cm on the 10-cm visual analogue scale, we are confident that patients could achieve longer periods with both types of exercise, although this requires confirmation.

The reasons for adherence to exercise programs are complex. Enjoyment and perceived competence in an activity or exercise have been suggested to be among the most important (Prasad and Cerny 2002). Participants in the current study enjoyed the gaming console exercise more than the standard care exercise. However, novelty may have contributed to this. Despite the widespread availability of gaming consoles, few participants reported using the type in the current study prior to participation in this study, though this was not formally recorded. Anecdotally, some of the study participants have purchased a gaming console subsequent to participating in this study and continue to use them in their exercise program. A longer exercise program using gaming consoles needs to be investigated to determine if these factors affect adherence and outcomes.

A limitation of this study is that it examined only one short session of each exercise. Longer periods of exercise and longer duration programs should also be investigated, ideally using a randomised study design. The SenseWear Pro armband may have introduced another limitation in the measurement of energy expenditure. Gaming console exercise may involve more vigorous upper limb activity compared to exercise on a treadmill or cycle ergometer. In addition, the device has not been specifically validated for upper limb exercise and for some people, walking or running on a treadmill may involve holding onto the handrail (Wass et al 2005), thus limiting upper limb movement. This might limit the accuracy of the energy expenditure measurement.

In conclusion, in this group of adults with cystic fibrosis being discharged from hospital after recovering from a pulmonary exacerbation, participation in an exercise program using a gaming console appears feasible. Cardiovascular demand and energy consumption were comparable between the two types of exercise and greater enjoyment was reported when using the gaming console than when using the treadmill or cycle ergometer.
Footnotes: ¹Nintendo Model No. RVL-001(AUS), ²WiiTM EA Sports ActiveTM Model No. RVL P R43P-AUS, ³Nellcor N-20PA Handheld Pulse oximeter, ⁴Body Media, Pittsburg, PA

Ethics: The Prince Charles Hospital Human Research Ethics Committee approved this study. All participants gave written informed consent to participate in the study before data collection began.

Competing interests: None declared.

Correspondence: Dr Suzanne Kuys, Allied Health Research Collaborative, Metro North (Northern Cluster) Health Service District, The Prince Charles Hospital, Rode Road, Chermside, Queensland 4032, Australia. Email: Suzanne_kuys@health.qld.gov.au

References